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ENERGY CONSERVATION STRATEGIES

Marquis R. Seidel, et al

Environmental Protection Agency
Washington, D.C.

July 1973

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EPA-R5-73-021
July 1973

ENERGY CONSERVATION
STRATEGIES

by

Marquis R. Seidel
Steven E. Plotkin
Robert O. Reck

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TABLE OF CONTENTS

Page
Abstract . . . ii
List of Tables . . . iv
List of Strategies . . . v
Preface . . . vi

Sections
I Introduction and Summary . . . 1
  Introduction . . . 1
  Summary and Conclusions . . . 3
  Quantitative Results . . . 6
  Possible Tactics . . . 8
II Overview and Analytic Framework . . . 10
  Demand Projections & Elasticities . . . 12
  Potential Energy Conservation Strategies . . . 20
  Costs of Energy Conservation . . . 25
  Strategies for Allocating Costs . . . 26
    Price Policy . . . 26
    Flow Taxes . . . 34
    Stock Taxes . . . 35
  Strategies for Changing Demand Directly . . . 36
    Public Investment . . . 36
    Loans and Credits . . . 37
    Regulation . . . 38
    Exhortation and Education . . . 38
  Future Research . . . 39
III The Residential/Commercial Sector . . . 40
  Market Strategies . . . 42
  Non-Market Strategies . . . 45
  Energy-Saving Technology & Benefits . . . 47
  An Example . . . 63
IV The Industrial Sector . . . 70
  Market Strategies . . . 74
  Non-Market Strategies . . . 76
  Energy-Saving Technology & Benefits . . . 77
V The Transportation Sector . . . 87
  General Discussion . . . 87
    Pathways to Conservation . . . 88
    Inter-City Freight . . . 88
    Inter-City Passenger . . . 90
    Urban Passenger . . . 91
    Interactions of Energy Strategies . . . 93
  Short-Term Strategies . . . 93
  Mid-Term Strategies . . . 104
  Long-Term Strategies . . . 110
VI References . . . 113

LIST OF TABLES

Table		Page
I	Energy Consumption in U.S. by Use, 1960 & 1968	13
II	Forecasts of U.S. Energy Requirements by Sector. . . .	14
III	Partial Elasticities of Demand for Electricity	17
IV	Fossil Fuel Use for Electricity Generation	17
V	Suggestions, Office of Emergency Preparedness.	21
VI	Market Failure and Its Causes.	23
VII	Demand with Current & Altered Electric Rates	30
VIII	Typical Residential Electric Bills	43
IX	Savings from Standard Insulation	48
X	Sensitivity of Optimum Insulation.	49
XI	Fuel Consumption with Heating/A-C Systems.	61
XII	Specifications, Characteristic & Design House.	64
XIII	Specific Concepts and Energy Savings	65
XIV	Energy & Dollar Savings, Design I & II, Concepts . . .	66
XV	Energy in Metal Production and Recycling	78
XVI	Energy Savings on Automotive Metals.	79
XVII	Electricity Use in Construction.	82
XVIII	Modal Shares & Efficiency by Transport Sector.	89
XIX	1980 Freight Traffic with 1960 Modal Splits.	105
XX	1980 Passenger Traffic with 1960 Modal Splits.	105

LIST OF STRATEGIES

Strategy Page

O-1: REVIEW AND REVISION OF RATE-SETTING POLICIES 26

O-2: INTERNALIZATION OF ENVIRONMENTAL COSTS TO USERS. 33

R-1: Increase Residential and Commercial Insulation. 47
R-2: Increase Consumer Awareness of Energy-Saving Alternatives . . 47
R-3: Remove Institutional Barriers, as in FHA Appraisal Rules. . . 55
R-4: Control Quality of Energy-Saving Installation 55
R-5: Encourage Energy-Awareness in Appliance Choice. 62

I-1: Encourage Recycling of Selected Materials 77
I-2: Promote Energy-Saving Materials in Manufacturing. 77
I-3: Promote Energy-Saving Materials in Construction 81
I-4: Promote Investments in Energy-Saving Equipment. 83
I-5: Encourage Energy-Saving Shifts in Illumination. 84

T-1: Improve the Competitive Position of Rail Freight. 93
T-2: Improve the Energy-Efficiency of Trucks 94
T-3: Centralization of Truck Terminals 95
T-4: Raise Automobile Operating Costs. 95
T-5: Increase Energy-Efficiency of Auto by Technology. 96
T-6: Improve Airline Passenger Load Factors. 98
T-7: Raise Urban Operating Costs of Autos (Parking Fees & T-4) . . 99
T-8: Subsidize Short-Term Improvement of Existing Transit. . . . 100
T-9: Promote the Use of Fringe Parking Facilities. 101
T-10: Initiate the Restructuring of Urban Transportation. 101
T-11: Promote Technological Improvements of Autos (T-5) 102
T-12: Promote Carpooling. 102

PREFACE

In September 1972, the Deputy Administrator of the Environmental Protection Agency charged its Office of Research and Monitoring (OR&M) to perform a background study on various strategies for reducing national energy demand, as one option among many to be evaluated for reducing environmental pollution. Such a study was already under way within the Implementation Research Division (IRD) of OR&M, as part of its continuing research on the subject.

This report is the result of that study, and can also be considered as a progress report on IRD's program of research on energy conservation. It deals first with restoring proper market functioning, then with the effects of energy price increases, and finally with selected regulatory actions. At all times, it tries not to advocate more or less energy conservation, but rather to evaluate alternative means of reducing energy use, if it should be decided by the political process that such reductions are in the national interest.

This effort included many participants. EPA's Energy Policy Committee is to be thanked for its helpful comments, and for insisting that the study must not consider strategies based only on regulation or on price, but instead must treat a mixed strategy as was finally done.

The authors wish to express their gratitude for the assistance and motivation they received from other participants, and for the support and encouragement offered throughout the Office of Research, without which the study could not have been completed. Needless to say, any errors are our own responsibility.

SECTION I

INTRODUCTION AND SUMMARY

INTRODUCTION

The "energy crisis" is popularly viewed as an apparent inability of the energy industry to supply growing "needs" for energy. This report faces the issue of how the Environmental Protection Agency might respond to the threat of such a crisis. Increasing pollution control requirements will be viewed as exacerbating the crisis by increasing energy costs, and we will be urged to relax such measures, to permit continued expansion of supply.

Stated in more dispassionate terms, the "energy crisis" is a projection that at existing prices, historical growth of energy demand will probably outgrow the available energy supply. In fact, the "increased energy costs" arising from pollution control are simply the internalization to the energy supplier of the social costs which have, until now, been dumped into the environment. Energy suppliers should pass these costs on to consumers in such a way that energy resources are allocated efficiently. Anticipated higher energy prices will reduce demand. Thus environmental protection is not part of the problem; it is part of the solution.

In his Energy Message of June 4, 1971, President Nixon noted that "part of the answer lies in pricing energy on the basis of its full costs to society. The costs....are not now included in the price of the product. If they were added to that price, we could expect that some of the waste in the use of energy could be eliminated." This report is a beginning toward achieving that goal; an effort to estimate both the magnitude and the distribution of the effects of reasonable price increases on the demand for energy and for energy-using or energy-conserving products.

The "Overview" of this report examines rate revisions and cost internalization as two basic strategies. Later sections discuss particular savings in various sectors of the economy and non-market strategies for achieving them. The latter must not be viewed as substitutes for the former. The basic strategies are essential; the particular suggestions by sector may or may not still be needed once the basic changes are under way.

Scope of the "Energy Crisis"

In 1970, total U.S. energy consumption amounted to 68.8 QBTU (Quadrillion British Thermal Units, or "Quads".) In 1990, demand is projected to reach 135 QBTU, far above projected supply at current prices. The differences among consuming sectors are apparent from the distribution (with allocation of electricity and heat loss to users) of the total energy demand and its growth:

Sector	1970	Growth	1990
Households & Commercial . .	240 (34%)	58%	380 (28%)
Industrial	290 (42%)	124%	650 (48%)
Transportation	160 (24%)	100%	320 (24%)

It must be emphasized that such a growth projection is a continuation of historical patterns of energy consumption, with energy supplies expected to somehow grow to meet demand, without any significant change in the real costs of energy sources. That is, no "energy crisis" is assumed, and the supply or price of the required energy is not considered.

Basic Strategy Options

Given such demand projections, the nation appears to have a choice among three broad strategic options for resolving the "energy crisis":

1. Take no action (leaving a "gap" between supply & demand);

2. Reduce demand by
    a) Modifying energy-wasteful government policies,
    b) Internalizing environmental costs to users, and
    c) Assisting the market-place on a selective basis; or

3. Increase supply, by relaxing environmental constraints and by government funding of research and development.

SUMMARY AND CONCLUSIONS

This report explores the effects of choosing the second option. The basic finding of this report is that if the government should wish to take an activist position on behalf of energy conservation, a market-based strategy appears attractive. Large amounts of energy go for uses that could be eliminated at very little cost; such energy savings would not call for changes in life style, cessation of national growth, or significant economic dislocations. If such low-priority energy uses (or wastes) are not eliminated, it will become far more difficult to maintain (much less improve) environmental quality. Thus the process of allocating environmental costs to energy suppliers (and through them to users) is part of the solution to the energy problem, not part of the problem itself. In more detail, it has been possible to identify a number of the specific areas where such savings are economically viable, and to consider what additional government action, if any, might be taken to ensure a sound market if this approach should be adopted.

Current emphasis is on energy conservation through "voluntary" programs. The American consumer seems to be quite willing to cooperate in such programs in the short run, when he believes the purpose is valid. However, he seems unwilling to make economically unsound choices for any great length of time; and he seems very quick and willing to make economically prudent choices. He has more common sense than to ask for higher prices, but he doesn't seem to be clamoring for especially low energy prices any more. For these reasons, it behooves policy-makers to give careful consideration to the means by which the "voluntary" actions which are needed can be converted into economically rational actions on the part of consumers.

A number of areas have been identified where further research is needed on the optimum allocation of scarce energy among users. A broad research program on the economics of energy use and conservation is needed, to deal with the long-run impacts of such alternatives as continued exponential expansion of energy supply. The nature of these research needs is specified in Section II.F of this report; specific needs for technology research are mentioned in passing. The three most pressing economic questions deal with the energy-efficiency of transportation alternatives, the rate structure for electricity, and the burden of and response to increased residential heating costs.

Allocation of Energy Costs

The basic question about closing the "energy gap" is whether the costs of closing it should be borne solely by society generally, investing in expanded supply; solely by consumers, restricting certain kinds of demand; or by market processes which allocate energy increments to those users who are willing to pay the full social costs of added uses.

For market forces to work effectively, government policies that indirectly encourage energy waste would have to be revised. The most obvious such policies are electric rates that give lowest prices to users with the most flexibility, and natural gas price regulation that not only restricts supply, but also encourages waste of the gas that is available.

Environmental damages are real costs to society. We cannot fully estimate the magnitude or distribution of these costs, but we can discuss the energy-saving alternatives that become economical when energy costs increase by any specific amount.

Residential/Commercial Savings

Even at current energy prices, added insulation would pay for itself in most cases. A 25% increase in fuel costs could make it economical to save 50% of residential heating/cooling needs in new units, and about half that amount in existing units, using available equipment and techniques.

Consumers need more understanding of the energy-use alternatives, both in housing construction and appliance choice. The governmental role might include standards, labeling, appraisal practices, and regulation, but there seems to be no need for restricting consumer choices.

Industrial Savings

If industry's 1970 demand of 29 QBTU rises to the projected 65 QBTU in 1990, it will be because industry is encouraged to continue under-valuing energy, and shifting toward energy-intensive products and processes. It is important to remember that most of 1990's industrial energy use will be from equipment that has not yet been built.

If an activist national policy of energy conservation were adopted, market strategies could make many energy-saving choices worthwhile for industry. Options include more recycling of energy-intensive materials, use of energy-saving materials in manufacturing and construction, and investment in energy-saving processes and equipment.

Transportation Savings

At least in the short term, greater savings are available from increased auto efficiency than from shifting to alternative modes of passenger travel. For the longer term, it is desirable to reverse the trend to less energy-efficient modes of transport.

Auto owners can become more aware of fuel-saving options, such as radial tires, better load-to-engine match, smaller cars, and better aerodynamics. Increased operating costs, partly due to pollution controls, will foster this awareness. Rate-setting bodies might allow natural competitive advantages to favor energy-efficient modes, rather than trying to cancel such advantages in the name of inter-modal competition. Planning for urban transport systems might consider energy conservation along with abatement of congestion and pollution.

QUANTITATIVE RESULTS

Specific savings will be estimated for specific conservation actions, but to summarize these quantitative findings is very difficult because of the overlap among strategies. We find an estimated 1985 savings of 7 Quads in Residential/Commercial and Industrial, due solely to estimated sector elasticities responding to proposed electric rate realignments with no net cost increase, and 4 Quads in Transportation to changes in auto efficiency that are cost-effective at present prices.

Beyond this, but far short of supply-side estimates of prices doubling and tripling, it appears that net price increases on the order of 25% (leaving real energy costs below their 1960 level) would lower 1990 demand projections by a total of some 41 Quads, or about 30%. This means that energy needs would grow by less than 40% between 1970 and 1990, rather than the energy-crisis projection of 100% increases.

Such growth would consist of continued rapid expansion of most of the economy, with some revisions and cutbacks of growth trends in the more energy-extravagant sectors. It is intuitively obvious that a 25% increase in real prices over a 17-year span will not be catastrophic: at most, energy would require 1%-2% more of GNP. This report tries to examine the substance of such an intuition, and to specify strategy and tactics for achieving an orderly transition to a national concern for energy conservation, should such a policy direction be chosen.

The results are basically optimistic. The Presidential hopes:---"homes warm in winter and cool in summer, rapid transportation, plentiful energy for industrial production and home appliances" and "less of a strain on our overtaxed resources" appear to be well within our reach.

ATTRACTIVE STRATEGIES

* OVERALL
  - Dual Strategy, Using both Market and Regulation.
  - Broad Research on Energy Use and Conservation.

* REVIEW AND REVISION OF ENERGY-WASTEFUL GOVERNMENT POLICIES
  - Discriminatory Pricing
  - Highway and Aviation Subsidies
  - Depletion Allowances

* INTERNALIZATION OF ENVIRONMENTAL COSTS TO USERS
  - Sulfur Emissions Tax
  - Auto Emissions Tax
  - General Costs of Compliance

* ASSISTING MARKET WITH SELECTIVE ACTIONS
  - Insulate New Dwellings: Regulation and Labeling
  - Insulate Old Dwellings: Subsidy or Loan
  - Control Trends to Energy-Wasteful Products, Processes
  - Improve Automobile Energy-Efficiency

* POTENTIAL SAVINGS IN 1990, GIVEN ABOVE STRATEGIES
  - 22% of Residential/Commercial - - 8 QBTU or 6%
  - 34% of Industrial - - - - - - 24 QBTU or 17%
  - 27% of Transportation - - - - 9 QBTU or 7%
  - NATIONAL - - - - - - 41 QBTU or 30%

POSSIBLE TACTICS

It is desirable to translate the study's list of energy-saving strategies into more specific tactics that might be used when and if energy conservation becomes a national policy. It is not our purpose here to recommend policy, strategy, or tactics. Very few of the requisite decisions will, or should, be made within EPA.

However, it has been possible to enumerate some of the agencies that have the responsibility for making such decisions. In many cases, decisions that are relevant to the use or conservation of energy are now under active consideration, sometimes with little or no explicit consideration of energy itself. The specific energy-saving tactics are cross referenced to the relevant strategy discussions within the body of this report, and are arranged in an order based on an approximation of "immediacy" — an estimate that the tactic is either easy to begin, or worthy of prompt consideration if energy conservation is to be actively pursued.

At most of these decision points, more evaluation will be needed than has been possible within the scope of this report. We have remarked on the lack of data and analytic tools for dealing with many of these aspects, and are engaged in research which will clarify the most urgent of them.

One final warning: we have not always been able to consider the transient, or short-run, problems of adjusting to policies of energy conservation. There are always legitimate interests which will be hurt more, or helped less, by any shift of government policy. Many such interests will perceive that the effects of a specific tactic, on them, will be the opposite of the effect on the nation as a whole. Policy-makers must be aware that such transitory effects do not vitiate our evaluations.

TACTICAL DECISION POINTS

AGENCY	POSSIBLE CONSERVATION MEASURE	STRATEGY	PAGE
FPC	Help states appraise long-term energy costs	O-1	26
FPC	Define & apply cost-based and peak-load pricing	O-1	26
EPA	Direct focus on environmental costs	O-2	33
All	Increase consumer energy-awareness	R-2	47
FPC	Revise interstate rates for electricity	O-1	26
FPC	Revise natural gas well-head prices	O-1	26
FPC	Issue guidelines on promotional advertising	O-1	26
HUD	Consider energy costs in appraising property	R-3	55
DOT	Encourage radial tires, especially on new cars	T-5	96
DOC	Promote industrial energy-awareness, products	I-2	77
DOC	Promote industrial energy-awareness, processes	I-4	83
HUD	Apply existing FHA-51A insulation standards	R-1	47
EPA	Influence operating costs of automobiles	T-4	95
HUD	Set energy standards for commercial buildings	I-3	81
DOT	Improve load-to-engine match	T-5	96
FTC	Require energy-cost labeling of appliances	R-5	62
ICC	Review/revise rates for energy-efficiency	T-1	93
DOT	Improve energy-efficiency of trucks	T-2	94
DOT	Promote small automobiles	T-5	96
EPA	Increased energy-saving industrial recycling	I-1	77
HUD	Set standards for installations	R-4	55
DOT	Expand R&D on energy-saving commuter systems	T-8	100
CAB	Increase aircraft passenger load factor	T-6	98

SECTION II

OVERVIEW AND ANALYTIC FRAMEWORK

This document outlines methods of reducing energy demand (or at least the growth of demand) and the benefits that might be obtained by each of these methods. The study deals with the Residential/Commercial, Industrial, and Transportation Sectors separately, discussing 1975, 1980, and 1990 time horizons within each sector.

Before treating these sectors specifically, it is necessary to clarify the viewpoint and the framework of the analysis. To do so, we must give some initial consideration to the nature of the projections of energy consumption, the costs of energy conservation, and the general types of strategy for altering demand, either by broad-based market mechanisms or by specific efforts to regulate energy uses. These initial considerations lead us to two very broad strategic suggestions. Both could be initiated as early as possible, and pursued steadily and dynamically throughout the whole period under consideration.

In his Energy Message of June 4, 1971, President Nixon noted that "Historically, we have converted fuels into electricity and have used other sources of energy with ever increasing efficiency. Recent data suggest, however, that this trend may be reversing.... We must get back on the road of increasing efficiency.... We believe that part of the answer lies in pricing energy on the basis of its full costs to society. One reason we use energy so lavishly today is that the price of energy does not include all of the social costs of producing it. The costs incurred in protecting the environment and the health and safety of workers, for example, are part of the real cost of producing energy --- but they are not now included in the price of the product. If they were added to that price, we could expect that some of the waste in the use of energy would be eliminated." This report is a beginning toward achieving this goal.

It is well known that if prices uniformly reflect the full social costs of goods, they will work to produce an optimum allocation of resources among competing needs. It is not sufficient, however, to affirm a rich faith in the market. It is also necessary to look at the present market in some detail, estimate the effects of changes in current prices, and project the distribution of social costs and benefits which will follow from such changes. Most important of all, it is essential to search carefully for cases of present or possible market failure, and to rectify or compensate for each of them. The present report is an effort to treat both the effects of pricing, and the cases where pricing alone is insufficient, in more detail than prior studies.

The results are basically optimistic. The Presidential hopes:— "homes warm in winter and cool in summer, rapid transportation, plentiful energy for industrial production and home appliances" and "less of a strain on our overtaxed resources" appear to be well within our reach.

The basic conclusion is that relatively large fractions of total energy consumption are being used, not because the energy is essential or desirable in itself, but because the energy is slightly cheaper than available energy-saving alternatives. Relatively small changes in price can be expected to make worthwhile a national return to greater efficiency in energy use. There is no reason to fear that such a trend will cause major dislocations in the economy.

DEMAND PROJECTIONS & ELASTICITIES

In 1970, total U.S. energy consumption amounted to 68.8 QBTU (Quadrillion British Thermal Units, or "Quads".) When electric energy (including waste-heat losses) is allocated to its ultimate users by sectors, the distribution of this total energy consumption appears as follows:

Households & Commercial	34.3%
Industrial	41.5%
Transportation	24.0%

The Utility & Electricity Generation Sector is treated as a transformation mechanism rather than as a specific consumption sector of the economy, and its fuel inputs are allocated to its ultimate consumers, throughout this report. This convention was adopted because we are not concerned directly with the efficiency of the conversion process, and because it seems important to view all demand on a consistent basis as a drain on the ultimate energy input resources available to the nation.

A more detailed tabulation of U.S. energy consumption, by end-use within sector, is presented in Table I for the years 1960 and 1968; the annual rate of growth of each use is also given.

In recent years there have been many studies of the determinants of energy demand. It is not easy to compare these studies to one another, because of the multitude of varied assumptions and methodologies contained in each. Consequently, they exhibit large variations in reported values of total energy consumption, energy requirements, and energy demand.

Nevertheless, most forecasts of energy demand contain assumptions in the following basic range:

- GNP growth rate about 4% per year;
- population growth rate about 1.6% per year;
- relative prices remain competitive; and
- unlimited availability of fuels.

Based on these and other assumptions, a number of projections of energy requirements by sector have been generated. A sample of such projections is given in Table II.

The third and fourth assumptions mentioned above are obviously not consistent with the existence of an "energy crisis". Clearly the gap between our demand projections and our supply projections will ultimately be closed, and each future year will have an energy consumption which is equal to both supply and demand. Clearly, also,

TABLE I - ENERGY CONSUMPTION IN THE UNITED STATES BY END USE 1960-1968

(Trillions of Btu and Percent per Year)

Sector and End Use	Consumption 1960	Consumption 1968	Annual Rate of Growth	Percent of National Total 1960	Percent of National Total 1968
Residential					
Space heating	4,848	6,675	4.1%	11.3%	11.0%
Water heating	1,159	1,736	5.2	2.7	2.9
Cooking	556	637	1.7	1.3	1.1
Clothes drying	93	208	10.6	0.2	0.3
Refrigeration	369	692	8.2	0.9	1.1
Air conditioning	134	427	15.6	0.3	0.7
Other	809	1,241	5.5	1.9	2.1
Total	7,968	11,616	4.8	18.6	19.2
Commercial					
Space heating	3,111	4,182	3.8	7.2	6.9
Water heating	544	653	2.3	1.3	1.1
Cooking	98	139	4.5	0.2	0.2
Refrigeration	534	670	2.9	1.2	1.1
Air conditioning	576	1,113	8.6	1.3	1.8
Feedstock	734	984	3.7	1.7	1.6
Other	145	1,025	28.0	0.3	1.7
Total	5,742	8,766	5.4	13.2	14.4
Industrial					
Process steam	7,646	10,132	3.6	17.8	16.7
Electric drive	3,170	4,794	5.3	7.4	7.9
Electrolytic processes	486	705	4.8	1.1	1.2
Direct heat	5,550	6,929	2.8	12.9	11.5
Feed stock	1,370	2,202	6.1	3.2	3.6
Other	118	198	6.7	0.3	0.3
Total	18,340	24,960	3.9	42.7	41.2
Transportation					
Fuel	10,873	15,038	4.1	25.2	24.9
Raw materials	141	146	0.4	0.3	0.3
Total	11,014	15,184	4.1	25.5	25.2
National total	43,064	60,526	4.3	100.0%	100.0%

Note: Electric utility consumption has been allocated to each end use.
Source: Stanford Research Institute, using Bureau of Mines and other sources.

TABLE IIa - FORECASTS OF U.S. ENERGY NEEDS (in TBTU), RESID./COMM.

Source(1)	1970	1975	1980	1985	1990	2000
EMUS	13837	15451	17265			21066
CGAEM	14246	17224	20983	25701		
EUS	14737	17559	21269	26028		
RAF	16430		21110			27600
OEUS(2)			11000			
PEC			17979			
OEP(3)		25843	29633		37329	

(1) Source Codes:

EMUS.....An Energy Model for United States Featuring Energy Balances for 1947-65 and Projections to the Years 1980 and 2000. Bureau of Mines, IC 8384, 7/68, U.S. Dept. of Interior

CGAEM....Competition and Growth in American Energy Markets, 1947-85. Texas Eastern Transmission Corporation, 1968

EUS......Energy in the United States, 1960-85. Michael C. Cook, Sartorius & Co., 9/67

RAF......Resources in America's Future. Landsberg, Fischman, Fisher; Resources for the Future, Inc., Johns Hopkins Press 1963

OEUS.....Outlook for Energy in the United States. Energy Division, Chase Manhattan Bank, 10/68

PEC......Patterns of Energy Consumption in the United States. Wm.A.Vogely, Bureau of Mines, U.S. Dept. of Interior, 1962

OEP......Energy Conservation, Office of Emergency Preparedness, 7/72

(2) Excludes commercial uses of energy.

(3) Includes waste heat from electrical generation (Table VII).

TABLE IIb - FORECASTS OF U.S. ENERGY NEEDS (in TBTU), INDUSTRIAL

Source(1)	1970	1975	1980	1985	1990	2000
EMUS	20370	22446	24633			32594
CGAEM	21649	26216	31591	37954		
EUS(4)	22093	26303	31576	38016		
RAF	21810		29100			55620
OEUS(5)			30000			
PEC			22231			
OEP(3)		34284	42563		65150	

TABLE IIc - FORECASTS OF U.S. ENERGY NEEDS (in TBTU), TRANSPORTATION

Source(1)	1970	1975	1980	1985	1990	2000
EMUS	15548	18733	21481			42749
CGAEM	15501	18376	21968	25836		
EUS	14303	16935	20002	23662		
RAF	12960		18530			37190
OEUS			24000			
PEC			21000			
OEP		19070	22880		32200	

(4) Excludes non-energy uses of fuels.

(5) Includes commercial uses of energy.

there will be some cost associated with closing the forecasted gap. To decide what costs should be incurred, and what segments of the economy should pay those costs, any social planner needs to know the elasticities which describe how each segment will react to such additional costs. Unfortunately, there is not very much good data on the demand elasticities for energy.

Studies on elasticity of demand for energy are almost entirely limited to electrical energy. Among the most-cited studies is that by Fisher and Kaysen entitled "The Demand for Electricity in the United States"(Ref.1) and that by Wilson entitled "Residential Demand for Electricity"(Ref.2). Wilson has also derived energy demand equations, using a cross-sectional approach rather than the time-series method of Fisher and Kaysen. In both studies, the variable to be explained is average electricity consumption per household. In addition, Wilson has differentiated between new, flexible, and locked-in consumers with respect to electric appliances. Those in the locked-in category find that the cost of altering the stock of appliances is too great in the short run to change energy consumption patterns in any significant degree; i.e., they are relatively unresponsive to changes in price, or their elasticity of demand is between 0 and -1 (Ref.3).

A comparison of the results of these demand studies appears in Table III. The table reveals that elasticity estimates for gas and electricity cost coefficients are somewhat higher in the Wilson case, a result which Wilson attributes to the use of his cross-sectional data. Wilson's negative income coefficient disagrees with results that would be anticipated and is probably the result of his choice of the number of rooms per household for the "size of household" variable instead of the number of persons per household. The former is correlated with the level of household income while the latter bears no necessary relationship to income.

The Federal Power Commission (Ref.4) indicates that the use of fossil fuels for electric power generation has recently been undergoing change. These changes are recorded in Table IV and reflect underlying market forces and associated price elasticities of demand for alternative fuels. A careful analysis of energy alternatives requires that these elasticities and cross elasticities of demand be determined so that market impacts of alternative energy policies can be determined.

Summarizing the results of several energy demand studies, we find that in the Fisher and Kaysen estimates of short- and long-run residential and industrial demand, long-run residential price has nearly no effect on energy demand. Similar results appear for the short-run case; i.e., the elasticity coefficient in either case is greater than -1.0. Fisher and Kaysen also hypothesize that since technological change has neutralized the effects of price on industrial demand and has

TABLE III - PARTIAL ELASTICITIES OF EXPLANATORY VARIABLES

VARIABLE	Anderson Resid.	Wilson Resid.	Fisher and Kaysen Resid.	Fisher and Kaysen Comm.	Fisher and Kaysen Indus.
Price of Electricity	-0.91	-1.33	-1.3	-1.3	-1.7
Price of Gas	+0.13	+0.31	+0.15	+0.15	+0.15
Household Income	+1.13	-0.46	+0.3	+0.9	+0.5
Size of Household	-0.85	0.49			
Winter Temperature	+0.18	-0.04			
Population			+0.9	+1.0	+1.1

TABLE IV - Fossil Fuel Use for Electric Power Generation as a Percent of Total BTU, by Census Region, 1960 & 1969.

REGION	Coal		Gas		Oil	
	1960	1969	1960	1969	1960	1969
New England	58	23	5	2	37	75
Middle Atlantic	78	57	8	9	14	34
East North Central	96	93	4	6	-	1
West North Central	47	55	52	44	1	1
South Atlantic	77	70	15	13	8	17
East South Central	92	89	8	11	-	-
West South Central	-	-	100	100	-	-
Mountain	26	55	66	42	8	3
Pacific	-	-	68	83	32	17
U. S. Average	66	58	26	29	8	13

Source: Federal Power Commission, "1970 National Power Survey", 1970.

made electricity a more important input into the production function, there is little reason to expect a higher sensitivity of industrial demand to price.

In Wilson's demand study, the long-run price elasticities range from -1.0 to -1.6 instead of the near-zero estimates of Fisher-Kaysen.

The Chapman(Ref.5) results indicate that substantial cost increases and reductions in population growth will combine to give a considerably lower growth of electricity demand in 1980-2000 than in 1950-1970. In addition, the short-run unresponsiveness of demand to prices is attributed to the behavior of stocks of appliances, and to other short-run inflexibilities. For New York State, long-run price elasticities of -1.3, -1.3, and -1.4 have been derived for residential, commercial, and industrial demand respectively.

Halvorsen(Ref.6) has estimated long-run price, income, and cross elasticities of demand for residential electricity. He has found a total long-run price elasticity of demand of -1.20 and an income elasticity of 0.61. The cross elasticity of demand with respect to the price of gas was estimated at 0.04. Finally, for residential demand alone, an elasticity coefficient of demand with respect to average price of -1.138 was derived.

What, then, do these demand studies tell us about the characteristics of electrical energy demand, and what are the implications of their results and conclusions?

First, the elasticity of demand figures reported above indicate that the demand for electric energy is, in the short run, largely unresponsive to changes in price. However, the long-run elasticities generally indicate a greater reaction. (An elasticity below -1.0, after all, indicates that total expenditures for electricity would actually decrease if prices rose.)

Relatively low income elasticities (smaller than 1.0) indicate that the proportion of income spent on electricity decreases as income rises; that is, price increases would have a regressive effect unless some effort is made to prevent this. (When a change in marginal rates alone is discussed later, this regressive effect is indeed prevented.)

The short-run inelasticity of demand for electricity can be attributed to three general characteristics:

1. the inflexibility of energy-using equipment with respect to its hourly and total consumption of energy;
2. the inflexibility of equipment usage rates for fixed levels of production or of household income; and
3. the high costs of scrapping or replacing the equipment.

According to most extrapolations of available data, the demand for electricity, if unchecked, will grow at an exponential rate into the next century. The possibility of such long-run exponential growth is questionable. Such projections have no analytic basis and are fraught with uncertainties. They do not account for the possibility of rapid changes in life styles, and they assume that the effects of urbanization and of changes in technology will occur at the same rate as in the past. Such forecasts are often deficient in several respects:

1. fuels are assumed in limitless supply, at constant prices;
2. impacts of new technology are not fully included; and
3. environmental constraints are largely ignored.

It must be emphasized that such projections assume continuation of historical growth patterns of energy consumption (including technological improvement, population growth, etc.) with energy supplies expected to grow to meet demand without any significant change in the real costs of energy sources. That is, no energy crisis is assumed and the supply or price of the required energy is not addressed. If the historical pattern which is being extrapolated is one which includes public efforts to achieve ever-lower fuel prices and a public disregard for environmental costs, as many believe, then the pattern is not a trustworthy guide to future trends.

Strategy Options --

Given such demand projections, the nation appears to have a choice among three broad strategic options for resolving the "energy crisis":

1. Take no action (leaving a "gap" between supply & demand);
2. Reduce demand by
   a) Abolishing energy-wasteful government policies,
   b) Internalizing environmental costs to users, and
   c) Assisting the market-place on a selective basis; or
3. Increase supply, by relaxing environmental constraints and by government funding of research and development.

POTENTIAL ENERGY CONSERVATION STRATEGIES

By way of background, it is instructive to note that the Office of Emergency Preparedness has recently estimated the sector-by-sector potential energy savings from various suggested energy conservation measures (Ref.7). Needless to say, further research is needed in each of these areas, along with estimates of their environmental implications. The OEP suggestions are summarized in Table V.

For the economist, the energy crisis may be analyzed in terms of three main components: probable cost increases as energy sources grow scarce, desirable price increases to reflect the true environmental cost of energy sources, and price shifts to adjust to changing relative costs of various energy sources. These three components, taken together, may well produce serious strains on the economy within the next few years.

Such strains can arise (and are beginning to become visible already) in two primary ways. First of all, changes in the status quo, or deviations from past patterns and expectations, are intrinsically hard on the economy's participants, partly because of sunk costs and the inflexibility of capital, and partly for such non-economic reasons as human inertia. Secondly, there may be legal, administrative, or institutional barriers which are too inflexible to permit rapid response of the economy to changing conditions, with resulting physical hardships from genuine material shortages; the effects of selective price controls on the mix of available petroleum products is exactly such a case.

The most that needs to be done for the first kind of problem is to try to predict future trends as accurately as possible, except for the cases where past government policies have locked users into particular capital choices and some relief seems equitable. With respect to the second problem, it is at least necessary that the actual workings of each "barrier" be well understood; many of these have sound non-economic justifications, but many others would probably be removed or modified if their economic effects were widely understood.

If energy prices reflected the full social and environmental costs of energy consumption, the economist's involvement in the energy crisis would be mainly a matter of forecasting the changes in real costs of energy sources. If the forecasts showed impending shortages, the government could alter prices so as to restrict the growth in use of that particular energy source. In fact, the price structure which prevails among energy sources at the present time is part of the problem, not part of the solution.

Some of the sources of market failure have been identified and are presented in Table VI. In addition to such general causes as

TABLE V - SUGGESTIONS BY OFFICE OF EMERGENCY PREPAREDNESS

SHORT-TERM MEASURES (1972-1975) ---

Residential/Commercial --

Establish upgraded construction standards and provide tax incentives and insured loans for improved home insulation.

Savings: 10%, 0.2 QBTU/yr.*

Industry --

Increase energy price to encourage improvement of processes and replacement of inefficient equipment; provide tax incentives to encourage recycling and reusing of component materials.

Savings: 6-11%, 1.9-3.5 QBTU/yr.

Transportation --

Conduct educational programs to stimulate public awareness of energy conservation in the transportation sector; establish government energy efficiency standards; improve airplane load factors; promote development of smaller engines and vehicles; improve traffic flow; improve mass transit and inter-city rail and air transport; promote automobile energy-efficiency through low-loss tires and engine tuning.

Savings: 10%, 1.9 QBTU/yr.

Electric Utilities --

Smooth out daily demand cycle by means of government facilitate new construction; decrease electricity demand.

Savings: 4%, 1.0 QBTU/yr.**

Residential/Commercial --

Establish upgraded construction standards and tax incentives and regulations to promote design and construction of energy-efficient dwellings including the use of the "total energy concept" for multi-family dwellings; provide tax incentives, R&D funds, and regulations to promote energy-efficient appliances, central air conditioning, water heaters, and lighting.

Savings: 14%, 4.8 QBTU/yr.

Industry --

Establish energy-use tax to provide incentive to upgrade processes and replace inefficient equipment; promote research for more efficient technologies; provide tax incentives to encourage recycling and reusing component materials.

Savings: 12-17%, 4.5-6.4 QBTU/yr.

TABLE V - SUGGESTIONS BY OFFICE OF EMERGENCY PREPAREDNESS

Transportation --

Improve freight handling systems; support pilot implementation of most promising alternatives to internal combustion engine; set tax on size and power of autos; support improved truck engines; require energy-efficient operating procedures for airplanes; provide subsidies and matching grants for mass transit; ban autos within the inner city; provide subsidies for intercity rail networks; decrease transportation demand through urban refurbishing projects and long-range land use planning.

Savings: 21%, 4.8 QBTU/yr.*

Electric Utilities --

Restructure rates for heavy uses to smooth out demand cycle; facilitate new construction. Savings: 4%, 1.1 QBTU/yr.**

LONG-TERM MEASURES (Beyond 1980) ---

Residential/Commercial --

Provide tax incentives and regulations to encourage replacement of old buildings by energy-efficient new buildings; R&D funding to develop new energy sources (solar, wind power.)

Savings: 30%, 15 QBTU/yr.

Industry --

Establish energy use tax to provide incentive for upgrading processes and replacing inefficient equipment; promote research in efficient technologies; provide tax incentives to encourage recycling and reusing component materials.

Savings: 15-20%, 9-12 QBTU/yr.

Transportation --

Provide R&D support for hybrid engines, non-petroleum engines, advanced traffic control systems, dual mode personal rapid transit, high-speed transit, new freight systems, and people movers; decrease demand through rationing and financial support for urban development and reconstruction.

Savings: 25%, 8.0 QBTU/yr.

Electic Utilities --

Smooth out daily demand cycle through government regulation; facilitate new construction; support R&D efforts.

Savings: 3%, 1.4 QBTU/yr.**

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* Savings figures refer to annual savings in last year of period. Percentages refer to savings as percent of sector consumption.

** Electric Utility savings are incorporated into projections.

TABLE VI - MARKET FAILURE & ITS CAUSES

* GENERAL ---

- Inflexibility
- Erroneous Expectations
- Mismatched Time Horizon

* REGULATORY PRICE DISTORTIONS

Fuel	Kind of Distortion
Gas	Well-Head Prices & Block Rates
Oil	Import Quotas & Allowables
Coal	ICC Shipping Rates
Nuclear	Price-Anderson (Hazard Insurance)
Elec.	Rates: by States, & by FPC for interstate

* ENVIRONMENTAL COSTS NOT FULLY INTERNALIZED DURING:

FUEL	Extraction	Distribution	Use
Gas	Sweetening	Pipelines	Nitrogen Oxides
Oil	Subsidence	Spills	Emissions
Coal	Strip Mines	Slurry	Emissions
Nuclear		Risk	Thermal
Elec.	/Fuels, above/	Wires	

misinformation, there are a number of specific sources in the form of regulatory pressures or environmental externalities which affect certain aspects of the extraction, distribution, and consumption of energy sources in specific sectors. (Externalities are market failures simply because they are "external" costs; i.e., costs to society which are not matched by prices anywhere in the market.)

This makes it highly desirable to begin development of conservation strategies by considering as a first step the implementation of a set of internally consistent costs for energy sources, and a price structure which reflects those costs. Assuming such a framework, and assuming further that increasing scarcity will produce increasing energy costs over the next few years, it is then possible to ask which sectors of the economy will bear the largest burden of these increasing costs. This general question is discussed in the next section, but the way in which these costs will actually be internalized to the Residential, Industrial, and Transportation Sectors of the economy is addressed in Sections III, IV, and V.

Following our general discussion of the costs of energy conservation, we proceed to discuss two separate kinds of broad government strategy which are common to all three sectors of the economy. The first set of strategies consists of methods for realigning prices and costs so as to reflect the desired changes in demand for energy. The second set of strategies are those which work directly on specific components of demand.

COSTS OF ENERGY CONSERVATION

Throughout the current discussion, "cost" will refer to the perceived cost changes which occur as a result of the energy crisis and the economy's reaction to the crisis. If there is an energy crisis at all, it arises because our current prices are too low to permit continued expansion of the energy supply while simultaneously stimulating demand. In this case, if prices were to rise to reflect scarcity and externalities, the total social costs should actually go down, but perceived costs will go up. This is true and inevitable regardless of government action. The problem is to minimize the detrimental impacts of these perceived cost changes. Actual consumption of energy can be lowered in two ways: by allowing increased prices (or a shift in the supply curve) to cause consumption to fall along the present demand curve, or by lowering the demand curve (e.g., by energy-saving technology.) In the former case, the economy is likely to respond to increased prices by creating the same shifts in demand (e.g., energy-saving technology) that would be the most cost-effective for the government to introduce in the latter case.

In either case, energy conservation has perceived costs as well as benefits. If less energy is used, either some potential users of energy will be shut out of the market while some actual users pay higher prices, or else some segment of the economy must make the investments which cause the demand curve to shift. The existence of these perceived costs should not cause us to lose sight of the expected reduction in society's total costs, associated with demand reduction.

It is not possible to define the size of the desired changes in energy consumption, or the size of the associated costs. Ultimately, it will be a political process that judges whether the benefits of additional conservation exceed the costs. What is possible is to bring relative costs into better alignment, to identify some of the sectors where the greatest benefits can be achieved at lowest cost, and to estimate the magnitude and impact of the costs associated with any given level of energy conservation.

The next two sections are devoted, respectively, to strategies which affect demand by changing costs, and to strategies which affect demand directly. In both cases, the considerations of this analytic framework cut across all sectors of the economy. Later, in dealing with specific sectors, parts of the framework must be applied to specific parts of the problem. Throughout, there will be an effort to note existing programs and policies which work against energy conservation, as well as new programs which are needed.

STRATEGIES FOR ALLOCATING COSTS

This section considers the price policies which have a direct effect on the relative costs of energy, as well as general taxes on real uses of energy (as flows) or on energy-using investments (as a stock.) ("Tax" is used in the broadest sense, so that, for instance, a subsidy is viewed as a negative tax.) Certain more specific fiscal measures, such as the investment tax credit or low interest loans, are to be deferred to the following section because they tend (insofar as they are specific) to work as direct inducements to shift the demand in selected sectors.

Price Policy

A great variety of government forces interact to prevent energy resource prices from matching the full social costs of those resources. A partial list of these forces can include rate-setting policies as applied to both utilities and shipping, oil import quotas, mineral depletion allowances, and income-tax preferences favoring energy-intensive single-family homes. Beyond these distortions of resource prices, there is the growing social cost of various externalitties all along the production chain. Such external effects include the long-run cost of resource depletion, the aesthetic and ecological impact of resource extraction, and the environmental pollution involved in energy transformation, distribution, and use.

There is an increasing awareness of the degree to which all these forces and effects are externalities which have economic causes and admit of economic remedies; the need is for an internalization of environmental costs to the economic agents who are not now paying those costs. This internalization takes the form of an effluent or emission tax or fee. (Imposition of standards on the energy sector, for instance, also forces such an internalization of costs, but only by an indirect and inefficient process.) However, very little analysis has been performed on the quantification or the internalization of costs associated with the extraction or depletion of minerals.

Price Regulations -

STRATEGY O-1: REVIEW AND REVISION OF RATE-SETTING POLICIES OF ENERGY-REGULATING BODIES, TO ELIMINATE LOWER BLOCK RATES FOR THE MOST PRICE-SENSITIVE USERS OF GAS AND ELECTRICITY.

Regulation has made sense, historically, because energy utilities are "natural monopolies": once the requisite investment has been made for extraction and distribution of energy by a particular firm, the marginal cost of added output is low, and the entry of competition is economically impossible. Therefore, the firm's prices should (according to "accepted" theory) be regulated to prevent its raising prices and restricting output, and therefore also the firm should charge lowest prices ("at the margin") to its most price-elastic customers, and highest prices (to cover capital costs) to its least price-elastic customers. This pricing theory is especially perverse with respect to energy conservation -- it explicitly gives low prices to those who are most apt to respond to low prices by increasing their energy use.

The problem with this theory is not that it is incorrect, but that it has become outdated. At the margin, added energy use is no longer cheaper, but more expensive. In the very short run, an extra kilowatt-hour or BTU is indeed cheap; but in the long run, counting the share of added capital for each unit of added demand, we are probably not gaining any more economies of scale. When we include the congestion costs of adding new plants, pipes or wiring in existing urban areas, marginal costs are clearly rising, not falling.

Research is needed to extend our regulatory theories for this case of marginal costs which increase over the long run, and to apply the theory to price determination. The problem is, of course, seriously complicated by such aspects as peak-load pricing, the marginal costs of servicing various customers, and the cost (to the utility) of varying priorities among its customers.

It is not being suggested here that all energy customers must be charged uniform rates -- though such a measure may prove desirable. It is being argued that discounts must not be offered to those very customers who are most sensitive to the discounts, for this policy (which is now pervasive) encourages over-use of energy by the heaviest users, and by those who would most readily cut back on that energy use, given the economic incentive of higher prices.

Historically, part of the rationale for this specific policy has been that regulatory bodies should not cause the utilities to lose their most price-elastic customers to other energy suppliers. This is a valid but obsolete concern. If EPA moves to internalize the environmental costs of each energy source (including, for instance, abatement of pollution from in-plant generation of electricity), and if all energy suppliers charge prices related to cost rather than demand, then it is best for users to be free to choose the lowest-cost source of energy, not be held captive by artificial rates.

One of the important aspects of this issue is the whole question of peak-load pricing. Peak loads determine the capacity needed for an energy system. For electricity, daily and seasonal peaks may not, of themselves, account for much of the energy consumption, but they do account for much of electricity's environmental impact. This happens both through the use of less efficient and more polluting equipment to supply the peak, and also through the environmental burden (e.g., land use problems) of power plant expansion. In addition, some energy-storage schemes seem to entail significant energy-conversion inefficiencies to smooth these peaks. Analysis of the problems of defining and collecting higher rates from peak-period users must be part of the suggested review and revision.

The chief obstacle to this suggested strategy is the fact that there will be differential effects among the suppliers and users of energy. Many of the heaviest users of electricity will feel the largest rate increases, for example, and will therefore feel a doubly heavy increase in costs. It is therefore imperative that any such changes be made in as equitable a form as possible, for all affected energy users and energy suppliers simultaneously. However, it must also be realized that the most-affected industries will also, by definition, be those which can most readily conserve on some of their present energy use, and which have had the most benefit from this discriminatory pricing in the past. In addition, the energy cost is probably not a major cost for such price-elastic firms, to the degree that elasticity would generally be less for essential inputs.

It should also be noted that regulation of freight charges produces similar distortions in the relative costs of energy sources (especially oil vs. coal). While these distortions undoubtedly affect fuel choices in some locations, it is doubtful that they have a major effect on the national consumption of energy.

Little quantitative analysis has been performed on the effects of altering the structure of electric rates. A recent study (Ref. 8) by the New York Department of Public Service for residential demand concludes:

> "Price elasticity of electricity for residential use at rates close to historic or prevailing rates can be expected to be negligible both in the short run (3-5 years) and in the longer run. The proportion of consumer budgets spent on electricity is far too low to make a cost that is readily responsive to price changes. At sharply higher rates (double or triple current schedules), the rate of growth in the demand for residential power for uses which require large amounts of power (e.g., air conditioning, water and space heating) may be dampened."

We reject some of this reasoning, as we feel that moderate price increases will have significant long-run effects. (Specifically, there is no evidence of a discontinuity in the demand curve, such that reductions are negligible until they become harsh.) Although electricity takes a small share of household spending, this is not sufficient reason to assume that households can not or will not react to changes in the price of electricity by altering their use of it. On the contrary, the elasticities previously cited show that there are such reactions. The problem needs thorough and detailed study (especially with regard to the phasing-out of old capital and appliances) rather than merely to be assumed away as hopeless. One of the major initial problems is that of determining (or approximating) the prices which are actually paid by various consumers for a marginal unit of electricity.

The Federal Power Commission does not publish (or even collect) statistics on the revenues received within each segment of the block rate structure, so it is not possible to perform a precise analysis of the effects of existing rates. However, they do publish statistics(Ref.9) on National Weighted Average bills for various levels of service to each sector, and on the sales, revenue, and number of customers in each sector. These can be used to identify typical marginal and average prices in each sector, and to estimate the effects of uniform pricing of electricity.

The technique for making such an estimate is as follows: the marginal rate charged to the heaviest use in a sector is taken as the marginal cost in that sector. The fee for minimum service, less the marginal cost for that minimum service, is taken as the fixed cost (for hookup, distribution, meter service, etc.) for a customer in the sector. The fixed cost times the number of customers gives a fixed revenue to the utility; the remaining revenues are divided by the total service to yield a uniform rate which is to be charged for all energy supplied to a sector. The bills for various levels of service are then recomputed. (Details of this process, for the Residential/Commercial and the Industrial Sectors, are described on pages 42 and 74, respectively.)

This process gives the utility the same revenue from each sector as at present, assuming the same consumption of electricity. The higher marginal rates to customers are assumed to cause a reduction in consumption which is predicted by the price elasticity of each sector. Thus the consumption of electricity and the revenues of utilities are reduced — but without inequitable transfers between them.

The consumption projected under these assumptions is shown in Table VII. In Table VIIa we show the demand in TBTU (with heat losses for electrical demand reflected in the consuming sector) for the Residential/Commercial, Industrial, and Transportation sectors, estimated for 1975, 1980, and 1990. An increase of 11% in the marginal price of electricity is postulated for the Residential/Commercial and Industrial sectors. Half of the elasticity is assumed to take effect by 1975, all of it by 1980. The Transportation sector is not affected at all, nor are the prices or direct use of coal, gas or oil. The savings which are due only to uniform electric rates are shown in Table VIIb; the changed consumption projection is shown in Table VIIc. This single

TABLE VIIa - Projected Energy Demand, Given Current Electric Rates.

	Coal	Petroleum	Gas	Nuclear	Total
1975					
Resid./Comm.	4451	8512	10349	2531	25843
Industrial	9347	8517	12840	3580	34284
Transportation	-	18050	1020	-	19070
1975 Total	13798	35079	24209	6111	79197
1980					
Resid./Comm.	4750	9745	10658	4480	29633
Industrial	10937	10475	14922	6230	42564
Transportation	-	21440	1440	-	22880
1980 Total	15687	41660	27020	10710	95077
1990					
Resid./Comm.	5513	11772	11617	8427	37329
Industrial	15046	14818	15863	19423	65150
Transportation	-	30400	1800	-	32200
1990 Total	20559	56990	29280	27850	134679

Source: "Energy Conservation", Table 1 A-1, OEP, July 1972. Data in TBTU's, with electrical waste heat allocated to final users.

TABLE VIIb - Projected Energy Savings, Given Strategy O-1.

	Coal	Petroleum	Gas	Nuclear	Total
1975					
Resid./Comm.	288	109	118	177	692
Industrial	445	191	195	336	1167
Transportation	-	-	-	-	-
1975 Total	733	300	313	513	1859 =2.3%
1980					
Resid./Comm.	623	283	165	627	1698
Industrial	1163	559	456	1171	3349
Transportation	-	-	-	-	-
1980 Total	1786	842	621	1798	5047 =5.3%
1990					
Resid./Comm.	772	305	156	1180	2413
Industrial	1955	780	392	3662	6789
Transportation	-	-	-	-	-
1990 Total	2727	1085	548	4842	9202 =6.8%

Source: Calculations on Table VIIa as described in text, to give effects, in input TBTU's, of constant-revenue shift to uniform electrical rates.

TABLE VIIc - Projected Energy Demand, Given Strategy O-1.

	Coal	Petroleum	Gas	Nuclear	Total
1975					
Resid./Comm.	4163	8403	10231	2354	25151
Industrial	8902	8326	12645	3244	33117
Transportation	-	18050	1020	-	19070
1975 Total	13065	34779	23876	5598	77338
1980					
Resid./Comm.	4127	9462	10493	3853	27935
Industrial	9774	9916	14466	5059	39215
Transportation	-	21440	1440	-	22880
1980 Total	13901	40818	26399	8912	90030
1990					
Resid./Comm.	4741	11467	11461	7247	34916
Industrial	13091	14038	15471	15761	58361
Transportation	-	30400	1800	-	32200
1990 Total	17832	55905	28732	23008	125477

Source: Table VIIa less Table VIIb.

strategy accounts for a saving of 6.8% of the whole energy demand in 1990; and 9.0% of the non-transportation demand.

Constraints of time and scarcity of data have made it impossible for us to make similar projections of energy savings should natural gas rates be readjusted or deregulated. A cursory review reveals, however, that regulation has probably produced more severe market distortions with respect to natural gas than with respect to electricity. Thus, it seems probable that readjustments in the price and price structure for natural gas will produce energy savings comparable to those we have demonstrated for the electrical sector.

It should be noted that projected shortages of natural gas in the fairly near future are expected to drive prices up. While this is generally discussed in the context of increasing supplies, such price rises can also be expected to significantly reduce demand. Thus, it would appear that an opportunity to rationalize prices for natural gas is at hand, and further, that these price increases can be expected to significantly ameliorate the "energy crisis" by reducing demand, as well as by increasing supplies.

Finally, it is clear that oil import quotas work to keep prices up. This report does not deal directly with the supply-side reasons for increasing oil imports; however, a tariff on oil imports would permit a more direct and market-related interaction between supply and demand than the quota system which has been in effect.

Cost Internalization -

STRATEGY 0-2: WORK FOR INCLUSION OF ENVIRONMENTAL COSTS WITHIN THE TOTAL COSTS OF ENERGY SOURCES.

One strategy to achieve this is to charge emission and effluent taxes. The arguments for this approach, though not yet universally accepted even within EPA, are sufficiently familiar that they will not be repeated here. The aspect which is most relevant strategically is that such taxes, once accepted as a principle and embodied into law, can be readily adjusted to reflect changing public perceptions of the benefits of saving or using resources.

The proposed sulfur emission tax is, of course, a member of this family. There are a number of environmental costs which are directly traceable to the production or use of energy, and which can reasonably be charged to the responsible process. In general: firms try to pass such costs to the consumer; prices will rise a bit and production will fall a bit; the environment will be cleaner by the amount which firms clean up plus the foregone production; consumption will shift toward less-polluting alternatives (because they are less costly.) To estimate the effects of such taxes, certain assumptions can be made about the price shifts which might equalize the marginal damages done by the several energy sources.

Less Important Strategies -

While oil import quotas undoubtedly raise the price of oil and restrict the supply, it does not seem that the price increment creates a major change in total energy consumption. The quota is therefore deemed insignificant to energy conservation, though it is surely important to the energy supply issue (and though a tariff is preferable to a quota). Likewise, income tax preferences such as the deduction of property taxes and of mortgage interest costs undoubtedly help encourage some single family homes — but they are also beneficial to some of the less energy-intensive alternatives, such as apartments and condominiums, as are the fast write-off and capital gains provisions. Energy savings from changes to income tax rules would be mixed and probably trivial.

Flow Taxes

By "flow" we differentiate energy use from energy-using equipment (or "stock".) The difference between a tax on energy and a change in prices of energy sources is mainly that the former (a flow tax) permits a quicker allocation of the relative costs involved in energy from each of the various sources, without the need for determining the exact social costs involved in each of the stages of production, and without the need for setting effluent tax rates and making effluent tax collections at each production stage. A second major difference is that a policy of direct taxes on use of energy from various sources would permit direct focusing on selected types of customers. For example, a tax on energy may be somewhat regressive, having a more significant impact on the poor than on the rich. If the increase in cost of energy is in the form of a direct tax on the energy use, its impact could more easily be altered by permitting, for example, an exemption (like that suggested from sales taxes) for low-income families.

This report will discuss specific places where a tax on energy might be helpful. A general energy tax is not suggested, unless as an interim measure while effluent/emission taxes are being developed. In other words, the first choice is definitely a set of charges such as those outlined in Strategy O-2, to internalize costs all along the production chain. Only if this is not done, should we consider a direct tax on end uses of energy.

Stock Taxes

A change in the price of an energy-using investment is what we refer to as a stock tax — that is, a tax on the investment, rather than on the energy use itself. This tax may be either positive or negative; an investment credit, for instance, is similar to a negative tax on the capital being purchased.

If we look upon the stock tax as being simply a capitalization of a comparable flow tax, then there are three kinds of reason for preferring the stock tax. One reason is that the consumer's time rate of discount may be different from the social rate of discount, so that the purchaser of a particular appliance might ignore the implications of the continuing energy bill he might incur, but would respond to a higher tax on his appliance at the time of purchase. (The same is true for commercial or industrial investment choices, though not necessarily for consumer-type reasons.) The second reason might be that we wish a tax to fall only upon new choices of investment: for example, removing the block-rate discount could be a hardship on owners of existing electric space-heating installations, and most of this hardship could be avoided by charging such a rate increase only to owners of new installations in the form of an initial tax on the equipment itself. The third reason might be for the purpose of directly influencing the selection of specific pieces of capital; this topic is dealt with in the next section, and more specifically in the following discussion of each of the sectors of the economy.

STRATEGIES FOR CHANGING DEMAND DIRECTLY

This section is concerned with strategies by which the government can, where desired, change the demand for specific energy uses in a direct fashion. No specific recommendations will be made within this section. Instead, we will set the framework for later discussion of the various techniques for altering demand, as might be appropriate for the specific economic activities that will come under consideration. The tools available range from direct public investment, through loans, credits and regulation, to simple exhortation or consumer information.

It will be assumed throughout that the specific goals to be accomplished are energy-saving, and that appropriate changes have already been made in the price structure of energy sources, so that the desired goals are indeed economically efficient in terms of energy conservation. The remaining issue among these various alternatives will be: given that the market is still not sufficient to achieve socially desirable energy conservation under an improved price structure, what direct measures might be appropriate in specific cases?

Public Investment

Once the social costs of energy use have been internalized, the primary economic reason for public investment is to capture certain economies of scale which are unlikely to be achieved otherwise. Two extreme examples of such economies of scale would be the construction of rapid transit systems on the one hand, and a massive retrofitting of household insulation materials on the other. (This is suggested, not because the economic inducements could not be made available to the homeowner, but because treatment of an entire subdivision might be vastly cheaper, or much more efficient, than a series of independent decisions by each homeowner in the subdivision.)

The investment and/or subsidy which might be required for a rapid transit system provides an illustration of yet another aspect of the policy dilemmas which complicate the issue of public strategy. Federal and local governments have invested heavily in providing for improved movement of private vehicles. It is unlikely that this subsidy can or should be removed, or that the relevant costs will be internalized by tolls or commuter taxes. A comparable investment in transit may therefore be sound public policy. At the same time, it should be recognized that a possible "Transit Trust Fund" would be prone to commit the same kind of resource misallocations, in time, that the Highway Trust Fund has committed. Investments and subsidies must be used only with the greatest caution, if at all, wherever there is any alternative opportunity to rely on sounder market mechanisms.

It seems clear that research into energy-saving systems and technology is among the public investments which will be required. Throughout the remainder of this report, the areas where research is specifically needed, with highest probabilities of early and significant returns, will be indicated as a by-product of our analysis of the potential energy savings. In general, we will not specifically suggest such research programs, partly because it is not clear that such research falls under the Environmental Protection Agency, but chiefly because additional research of some kind is needed in almost every area.

The general research needs are of three types. First, there must be economic research into the internalization of costs, discounting of mineral-resource depletion, and pricing based on long-run marginal costs (e.g., the costs of growth). Second, there must be physical research concerned with energy-saving technology itself. Third, it is imperative that much existing research (especially in urban design and land use planning) become far more aware of energy conservation as a planning factor.

Loans and Credits

Loans and credits are not considered to be economically efficient ways of inducing specific portions of the desired energy conservation. This is so mainly because the desired restructuring of the price system ought to create the appropriate balances among uses of electricity. However, the suggested price structure can too easily create serious inequities among users of energy. This is especially true with respect to those users whose capital choices, made under the existing price structure, would leave them locked in to seriously inequitable operating costs. Quite aside from the inequities themselves, such users might be a serious obstacle to implementation of the desired structures, unless some measures are taken to alleviate, at least temporarily, the strains which might otherwise be placed upon them.

Consider a home with an existing electric space-heating installation. The owner is presently the beneficiary of discounts, partly because he is an off-peak user of electricity. In addition, he is probably imposing larger- than-average social costs upon the environment. Restructuring rates will cause a very large increase in his energy bill. The increase may well be sufficient to induce him to change his heating equipment, but the required capital outlay is still a newly-imposed and inequitable burden. A program of low-interest loans or credits might well be the appropriate way to alleviate this inequity.

There is another kind of economic imbalance which might justify loans or credits, at least until the basic imbalance can be rectified. This is the case when some part of the existing economic system introduces effective price differentials between otherwise-equivalent choices. For instance, the corporate profit tax tends to make operating costs only half as significant to firms as their capital costs. If we wish to introduce life-cycle costing of equipment, it may be much more expedient to lower the capital cost by a loan or credit than to propose revision of the profit tax itself.

Regulation

While direct regulation is generally not an economically efficient means for allocating resources, there has always been public concern for the degree to which long-term investments can or will be made wisely in the absence of thorough consumer information. This is, for instance, part of the rationale for the existence of housing, plumbing, and electrical codes. Given the existence and desirability of housing codes, in particular, it is certainly desirable that such matters as home insulation be made to reflect the changing perspective on energy conservation.

There are Federal movements toward replacement of descriptive codes, in favor of performance codes. This kind of trend is to be encouraged, for it will make easier the energy conservation specification.

Exhortation and Education

We do not envision energy-saving propaganda. However, for the kinds of reasons mentioned above, it seems desirable that some systematic effort be made to inform the purchasers of energy-using equipment about the relative efficiency or expensiveness of alternative choices. This might take the form, for instance, of labeling appliances with expected energy consumption during a lifetime of standard use.

Campaigns like the "Save-a-Watt" effort aim at short-term changes in energy consumption and are likely to have only fleeting effect on a small part of the residential sector (Ref.12). They have not been demonstrated to have lasting effects. Further, they have not achieved the energy savings predicted for them, quite possibly due to continued promotional activities of the utilities during such campaigns.

Clearly, we ought to discourage the promotional programs of power companies. Though nominally aimed at off-peak users, they add greatly to energy-intensive investments. Education will be needed in many areas, to replace utility cultivated concepts based on the convenience of cheap energy. These concepts range from possible overestimates of lighting requirements (by everyone from parents to architects), to industrial biases which tend to neglect energy costs in favor of capital costs, for reasons which are not yet clear.

FUTURE RESEARCH

Areas of needed future research have been indicated at various places in the text of this report. Additionally, the development of complete strategies for energy conservation, including appropriate combinations of technology and governmental action, require a deeper understanding of the nature of possible trade-offs between total social benefits and total social costs of energy use. Before this can be done, certain research questions must be answered.

1. What is the relationship between energy use and quality of life?
2. What are the magnitudes of environmental impacts of alternative energy systems?
3. How are these impacts related to the range of technological performance of energy devices?
4. What are the maximum socially acceptable impacts?
5. To what extent is the marketplace an adequate discriminating mechanism with respect to energy problems and energy resources?
6. What are practicable alternatives to Federal regulation of the energy market?
7. What government policy is appropriate to assure industry and consumer access to adequate energy supplies?
8. What short- and long-term measures can and should be taken to alleviate power shortages?
9. What price changes are necessary to shift energy-use patterns?
10. Should rate and pricing schedules be changed to discourage marginal use rather than encourage it?
11. What economic measures should be taken to encourage the use of by-product heat and the adoption of total energy systems?

SECTION III

THE RESIDENTIAL/COMMERCIAL SECTOR

The residential and commercial sectors accounted for 54.7 percent of total electrical energy consumption and 34.3 percent of total energy consumption in 1970. This share is expected to decrease to about 27 percent by 1990; the sector's consumption will rise from 24.5 to about 38 Quads given current prices.

The residential share of this consumption is expected to be 22 Quads in 1990; this consumption is expected to be divided among fuels (including electricity) and end uses as follows:

END USE	TOTAL SHARE	ELECTRIC	GAS	PETROLEUM
Space Heat	46.3%	30.4%	36.1%	33.5%
Water Heat	12.6%	58.1%	36.6%	5.3%
Air Condition	11.2%	100.0%	-	-
Refrigeration	4.4%	100.0%	-	-
Cooking	4.3%	56.3%	38.5%	5.2%
Clothes Drying	3.4%	69.7%	28.9%	1.3%
Other	17.8%	100.0%	-	-

The 16 Quads of commercial consumption is divided in a comparable fashion; this fact, together with the difficulty of finding aggregate statistics about the commercial sector, compels us to treat residential and commercial as one.

Several observations can be made about the above division of energy consumption. First of all, of course, space heating takes almost half the energy; if we treat space conditioning, the share is much larger. The use labeled "other" is large in this projection; that is partly because it is the fastest-growing at the present time. A great deal of the present growth in "other" uses is to be found in heat pumps, which are neither space heating or air conditioning, but are a generally more efficient substitute for both. When this is taken into account, the total for space conditioning is in the range of 65-70% of the sector's total. Most of the emphasis of this section will accordingly be given to the topic of insulation and other ways to achieve comfortable space conditioning with less total expenditure of energy.

We do not give a detailed treatment to options for changing kinds of fuel use, but only deal with energy-saving changes to present kinds of fuel use. We ignore such switching options because by far the biggest question has to do with the choice of electric heat, and this question contains many uncertainties. It has been demonstrated that electrically-heated homes use less energy than combustion-heated homes. (In one case, the statistics even showed that they use less electricity.) Such numbers contain biases due to the typical locations of dwellings where one or another choice makes sense, and due to the much better insulation characteristics of dwellings with electric heat. Yet there are probably many cases where electric heat gives a net saving of energy and other resources; and certainly, a heat pump supplemented by electrical resistance heating probably is, or can be, the most efficient choice of all.

We will discuss the factors which lead to current choices, and the changes necessary to reduce energy wastage without inconveniences to consumers or dislocations of the energy or housing markets.

MARKET STRATEGIES

The primary approach to be followed for achieving energy demand reduction in the residential/commercial sector is one which tries to remove current artificial constraints to the operation of the market for energy. For this reason, the principal market strategy to be advanced is that of internalizing external social costs of the production and the use of energy. This is to be accomplished through changes in the prices of energy and energy resources so that these costs may be included in any private or social cost-benefit calculations. We therefore proceed to an investigation of the effects of altering the current electric energy rate structures on the demand for electric energy. Because of constraints of time and available information, we limit the discussion to prices of electricity, though the results should permit generalization to other fuel costs.

Privately owned electric utilities provided (Ref.10) 333.4x10*9 kWh to 49.8 million residential customers for $7.41x10*9 in 1970. The average monthly bill was $12.41 for 558 kWh. Publicly owned electric utilities provided (Ref.11) 57.8x10*9 kWh to 6.4 million residential customers for $.85x10*9, with the average monthly bill being $11.08 for 751 kWh. The "National Weighted Average" (NWA) bills for these consumptions (558 and 751 kWh) would be $11.37 and 14.24, respectively (Ref.9).

The difference between NWA and actual bills is partly due to intrinsically lower rates by publicly owned utilities, and partly a result of the locations where publicly owned utilities are to be found. The national revenues for public and private utilities are such that if we take 1.22 cents and 1.83 cents as their respective prices for a marginal kWh, they will retain their present revenues while charging a fixed "service fee" of $1.91 or $2.19 per month, respectively, to each customer. The national-average marginal price of electricity would be 1.64 cents per kWh, about 11 percent higher than the 1.48 cents marginal price now perceived by the average customer. Other studies (Ref.1,2) have indicated a price elasticity of -1.3 for residential consumption. This implies a saving of 14 percent of residential consumption of electricity.

Table VIII shows (for 1970 NWA bills) the hypothetical bill computed with a constant marginal price at various levels of demand, compared with the actual bills (i.e., given declining -- actually U-shaped -- marginal rates.) Table VIII illustrates the fact that such a shift of rates would not be regressive, as is often alleged. Indeed, the monthly bills would be lower at the 100, 250, and 500 kWh/month levels of consumption. This is so because the present rates offer low marginal prices in the range of 250 to 500 kWh/month, but higher marginal rates for the first 250 kWh and for those above 500 kWh. (This U-shaped structure is not a statistical anomaly of the NWA, but is built into the rates of individual companies.) In contrast to this rate structure, uniform rates would have the effect of giving lower bills to the smaller users, higher bills to the bigger users, and higher prices for extra electrical consumption to almost everyone but the very smallest users. In other words, we can (and should) increase the price of using extra electricity, while at the same time decreasing the total cost of the electricity used.

TABLE VIII - COMPOSITE RESIDENTIAL ELECTRIC BILLS

Consumption kWh/Mo.	Actual NWA Bill Cost/Mo.	Actual NWA Bill Avg./kWh	Marg/kWh	Hypothetical Bill ($2.07 + 1.64¢/kWh) Cost/Mo.	Hypothetical Bill ($2.07 + 1.64¢/kWh) Avg./kWh
100	$4.09	4.09¢		$3.71	3.71¢
			2.28¢		
250	$7.51	3.00¢		$6.17	2.47¢
			1.20¢		
500	$10.51	2.10¢		$10.17	2.05¢
			1.48¢		
750	$14.22	1.90¢		$14.37	1.92¢
			1.64¢		
1000	$18.31	1.83¢		$18.47	1.85¢

Published NWA bills for 1970 commercial uses of electricity do not permit this kind of calculation. Reported sales were about 287x10*9 kWh to 7.2x10*6 customers, for $5.88x10*9; approximately 3300 kWh/month for $68/month to the average customer, with revenues of 2.05¢/kWh. The NWA bills (Ref.9, p.xxi) show a charge of $96/month for this level of consumption, and an average charge of 2.39¢/kWh even at the 10,000 kWh/month level --- three times the average. These statistics (and a more detailed study of the bills of individual companies and the charges for available demand) fail to permit detailed calculation of a plausible modification of the rates actually being charged.

It seems likely, however, that lower marginal prices than tabulated are presently being charged. Revisions comparable to those suggested for the residential sector (11 percent) would produce comparable effects (14 percent decrease in consumption.)

It has already been calculated (in Table VII) that in 1990, this rate revision would save approximately 2.4 Quads of energy in the residential/commercial sector; this is about 6% of the sector's total 1990 energy demand. These savings are essentially costless; the savings will be undertaken because, at the margin, they are cheaper than the energy they save, but not because the total energy bill is higher than it used to be. (If this is not clear, refer again to Table VIII.)

In addition to the strategy of rate revision, we have the second market strategy of cost internalization. The former does not increase the aggregate national energy bill, but the latter does. When we add savings from the two separate strategies, we must beware of double-counting. We have already stated that there is no reliable measure of the benefits and costs of energy conservation from the second strategy, since there is no way to discover, at present, just how much environmental quality the nation desires. What we will try to do instead, is to estimate how much conservation may be achieved at relatively low cost, and discuss the magnitude of price increases which might achieve that saving.

It will emerge in Section III.C that structural changes and energy-saving appliance concepts which cost about $2000 would save about 8 Quads, and would pay for themselves if energy prices rose about 33% at the margin. If the half of residential energy which is electrical had a marginal increase of 11%, the price of basic energy inputs would have to rise an extra 25% to make all of these savings worthwhile. This 25% increase might be 10%-15% for environmental costs, and 15%-10% for scarcity premiums. (For comparison, an increase of 100% would return us to 1950 levels of energy price in constant dollars.)

NON-MARKET STRATEGIES

The economic, social, and political systems of this country are interspersed with certain institutionalized constraints which prevent the market from allocating resources efficiently. Certain broad categories of market failure were described in Table VI. In view of the nature of these economic, social, and political constraints, it may be necessary to supplement the market strategies discussed above with selected non-market strategies which would be implemented only temporarily, to provide direction and smooth the transition to an efficient energy market.

One of the most viable interim approaches to the conservation of energy in the residential/commercial sector is to increase requirements for insulation in FHA/HUD and other government sponsored construction. Such regulations should cover not only the amount and quality of the insulation material itself, but also the quality and method of installation.

A second interim measure is to grant subsidies to new construction developers in order to encourage the adoption of energy-saving techniques in construction. Such techniques are not, of course, exclusive of changes in insulation, but extend far beyond insulation requirements. They include, for example, the nature of the heating and air conditioning systems installed by the builder, the selection of appliances offered in a new dwelling, and the kind of design and construction chosen for a new office building or shopping center.

The two broad measures just mentioned are chosen because they both deal first of all with space heating, where the most energy wastage is available for potential conservation, and because the form of market failure presently at work is especially pervasive.

We do not know at this time just how much "energy conservation" is worth to the nation; that is, we do not know just what sort of charge or social cost is associated with preventing either the depletion of scarce resources, the reliance on foreign energy sources, or the environmental degradation which accompanies energy extraction and use. We also do not know just how much energy would be saved in response to the internalization of such social costs. Therefore, whether we rely on market strategies or on non-market regulatory methods, we do not know with any precision what social costs and benefits go with particular energy-saving efforts.

We do know, however, that much energy could be saved at very little cost; that space-heating wastage, in particular, could be reduced by measures that already pay for themselves in reduced energy bills or that would do so if energy prices were just a little higher. However, the builder and the purchaser each have deeply ingrained habits of not looking into the future with enough confidence to warrant the extra investment. The buyer may not plan on owning the building long enough to realize the energy savings. Prospective buyers are uncertain of the actual energy efficiency of a building, so that the seller is unlikely to fully recover his energy-saving investments. Appraisal procedures may not permit such investments to be included. Most of all, buyers are accustomed to assuming a standard level of insulation and a moderate energy bill, and paying relatively little attention to either. As we move to internalize social costs, and as people begin to perceive energy as a more scarce and expensive resource than before, some interim measures are clearly desirable to help the economy through this transition period.

ENERGY-SAVING TECHNOLOGY AND BENEFITS

The previous discussion has focused on methods of reducing energy demand and inducing energy savings through the use of market and general non-market mechanisms. This section will discuss the technological feasibility of saving energy, the benefits to be achieved, and the economic forces which will govern the various possibilities.

STRATEGY R-1: Increase Residential and Commercial Insulation.

Research by the Oak Ridge National Laboratory (Ref.13) shows substantial savings from increased insulation in the residential and commercial sectors. They have derived estimates of the energy and money savings from the use of either revised FHA-MPS insulation requirements or the economically optimum amount of insulation, as determined by them, as compared with the use of older FHA-MPS requirements. Table IX indicates that further upward revisions of insulation requirements would yield net social gains, including energy conservation objectives. Potential savings in energy consumption in both gas heating and air conditioning appear significant, ranging from 20 percent in Atlanta to 50 percent in New York. Energy consumption savings for electrically-heated homes range from 7 percent to 26 percent, since the high price of electrical heating has already produced a relatively high level of insulation in such dwellings.

A sensitivity analysis was performed by increasing first the capital cost of insulation, then the costs of gas and electricity, by 33 percent. Table X shows how such an increase in the capital cost of insulation reduces the optimum amount of insulation and the potential savings in annual cost and energy consumption, especially in warmer climates with cheaper energy sources. Positive savings are nevertheless still possible in all regions, compared with current insulation practices, even when the cost of insulation is increased by as much as one-third. An increase in the cost of energy naturally increases the optimum amount of insulation, with resultant energy savings. Further data appear in Figures 1-5 showing changes in heat loss and and energy cost as a result of alternative insulation levels. Figures 4-5 also show the annual energy saving.

STRATEGY R-2: Increase Consumer Awareness of Energy-Saving Alternatives.

Why are present insulation levels so far from optimum? Probably the simplest answer is that current regulations only attempt to define a minimum, not an optimum, level; besides, they were set when insulation cost more and energy cost less. Builders and HUD each have institutional constraints which emphasize initial costs more than operational energy savings; in particular, HUD faces Congressional

TABLE IX

MONETARY AND ENERGY SAVINGS FROM USING REVISED FHA-MPS STANDARDS
OR
ECONOMICALLY OPTIMUM AMOUNT OF INSULATION INSTEAD OF UNREVISED (PRE-JUNE 1971) FHA-MPS REQUIREMENTS

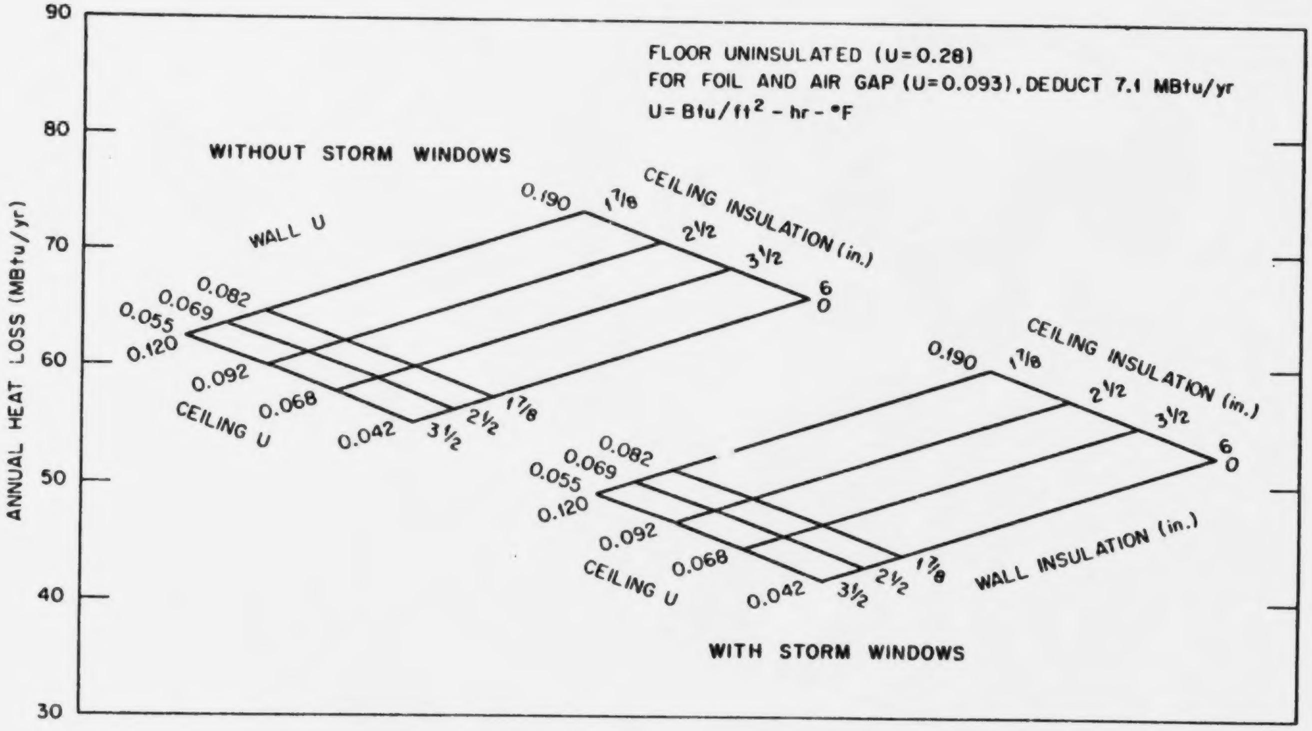
	Revised FHA-MPS Savings			Economically Optimum Savings		
	$/yr	Gas, %	Electricity, %	$/yr	Gas, %	Electricity, %
Atlanta						
Gas heat	6	16	—	6	31	—
Gas heat + A-C	3	12	0	6	20	7
Electric heat	36	—	16	87	—	53
Electric heat + A-C	21	—	10	63	—	39
New York						
Gas heat	28	29	—	32	49	—
Gas heat + A-C	28	24	10	37	50	26
Electric heat	75	—	19	155	—	47
Electric heat + A-C	47	—	13	135	—	42
Minneapolis						
Gas heat	37	37	—	42	43	—
Gas heat + A-C	39	37	11	45	43	18
Electric heat	80	—	22	119	—	29
Electric heat + A-C	82	—	22	122	—	29

Source: Moyers, John C., The Value of Thermal Insulation in Residential Contruction: Economics and the Conservation of Energy, Oak Ridge National Laboratory, 1971.

Table X. Economically Optimum Insulation and Resultant Savings with Increased Insulation or Energy Costs

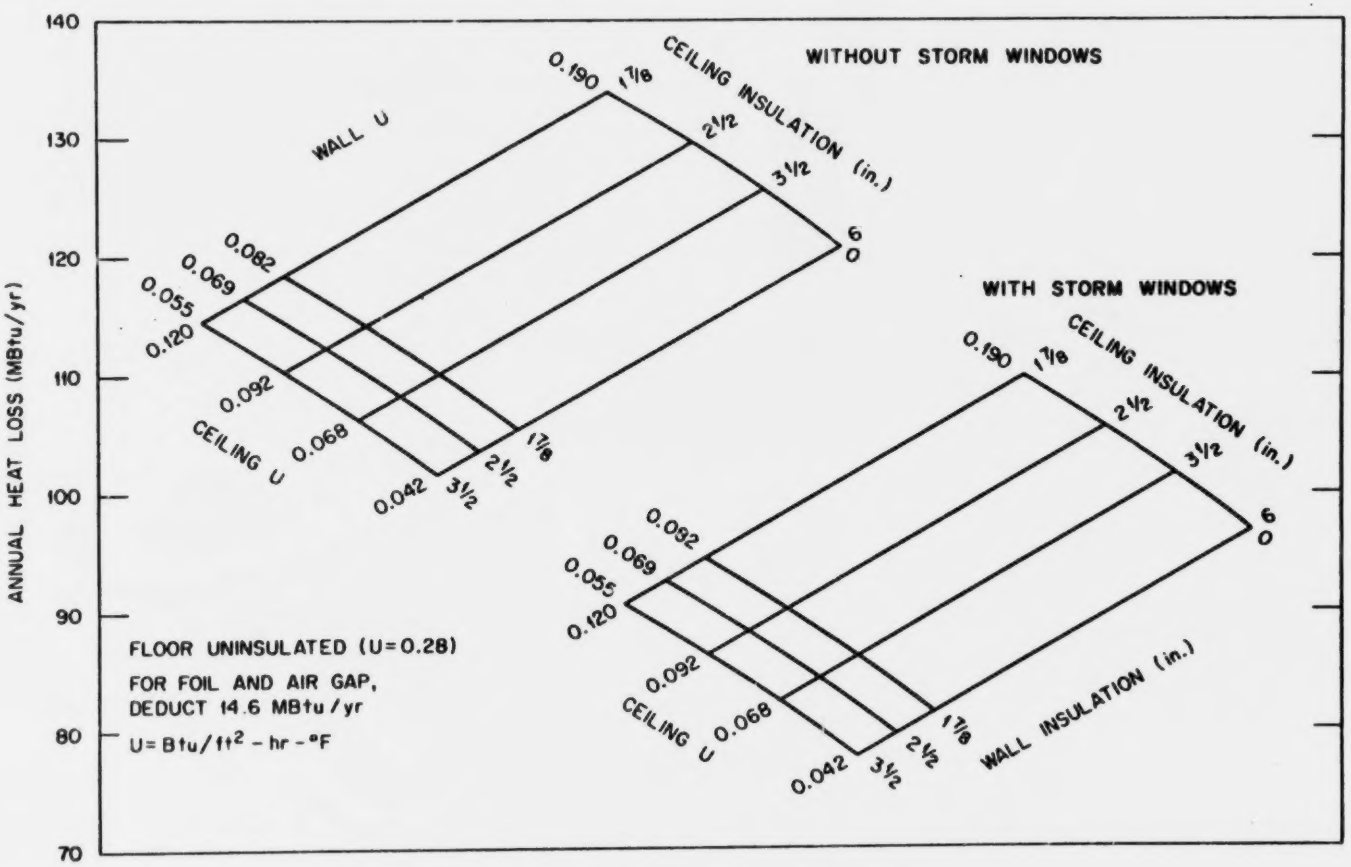
Region and Comfort System	Insul. Cost x 1.33							Energy Cost x 1.33						
	Windows	Floor	Ceiling	Walls	Annual Saving, $	Gas Consumption Reduction, %	Electricity Cons. Reduction, %	Windows	Floor	Ceiling	Walls	Annual Saving, $	Gas Consumption Reduction, %	Electricity Cons. Reduction, %
Atlanta														
Gas Heat	P	O	3-1/2"	0"	2	6	-	P	F	3-1/2"	3-1/2"	18	31	-
Gas Heat + A-C	P	O	3-1/2"	3-1/2"	1	4	3	SW	F	3-1/2"	3-1/2"	15	38	14
Electric Heat	SW	F	3-1/2"	3-1/2"	63	-	49	SW	F	6"	3-1/2"	131	-	53
Electric Heat + A-C	SW	F	6"	3-1/2"	44	-	39	SW	F	6"	3-1/2"	94	-	39
New York														
Gas Heat	P	F	3-1/2"	3-1/2"	20	32	-	SW	F	3-1/2"	3-1/2"	64	49	-
Gas Heat + A-C	P	F	3-1/2"	3-1/2"	22	27	12	SW	F	6"	3-1/2"	69	50	26
Electric Heat	SW	F	6"	3-1/2"	134	-	47	SW	F	6"	3-1/2"	218	-	47
Electric Heat + A-C	SW	F	6"	3-1/2"	116	-	42	SW	F	6"	3-1/2"	189	-	42
Minneapolis														
Gas Heat	SW	F	3-1/2"	3-1/2"	25	38	-	SW	F	6"	3-1/2"	73	43	-
Gas Heat + A-C	SW	F	3-1/2"	3-1/2"	28	38	14	SW	F	6"	3-1/2"	77	43	18
Electric Heat	SW	F	6"	3-1/2"	107	-	29	SW	F	6"	3-1/2"	165	-	29
Electric Heat + A-C	SW	F	6"	3-1/2"	109	-	29	SW	F	6"	3-1/2"	168	-	29

P = Plain Windows SW = Storm Windows F = Foil and Air Gap



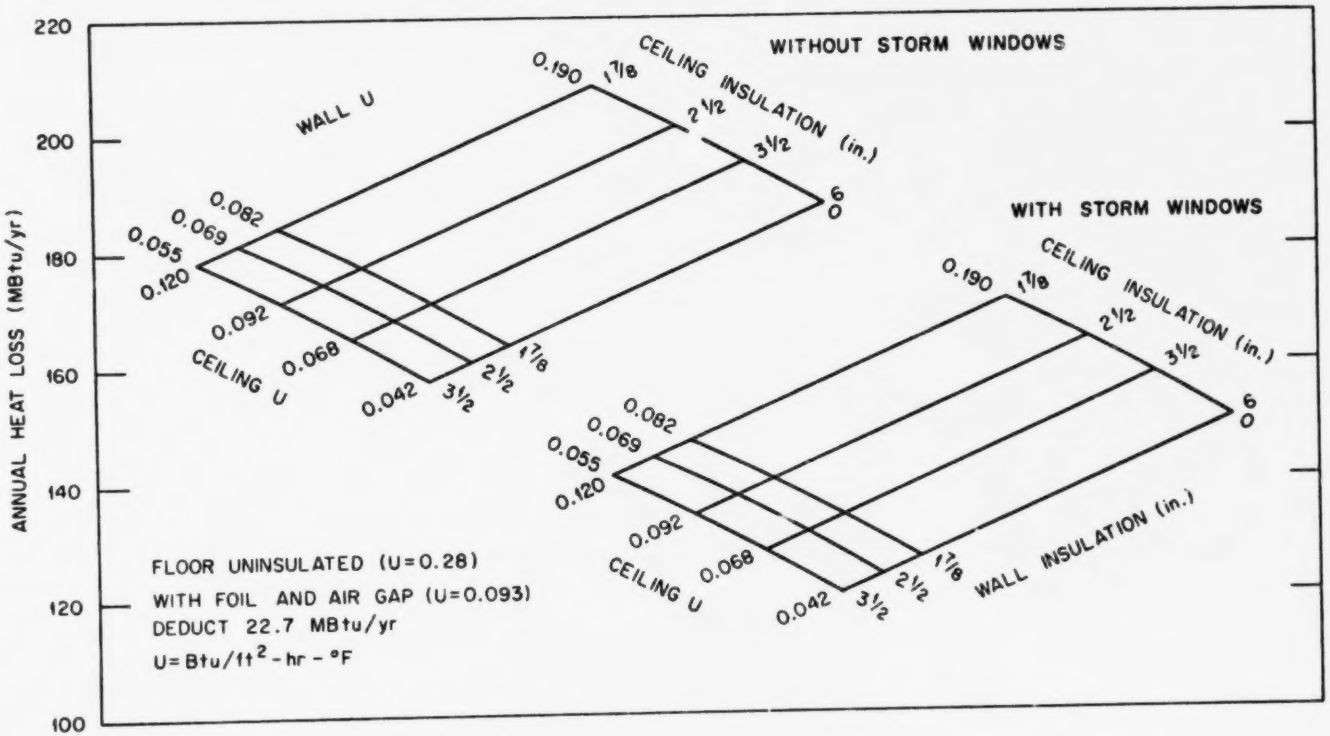
Annual Heat Loss: Atlanta Residence.

Fig. 1



Annual Heat Loss : New York Residence.

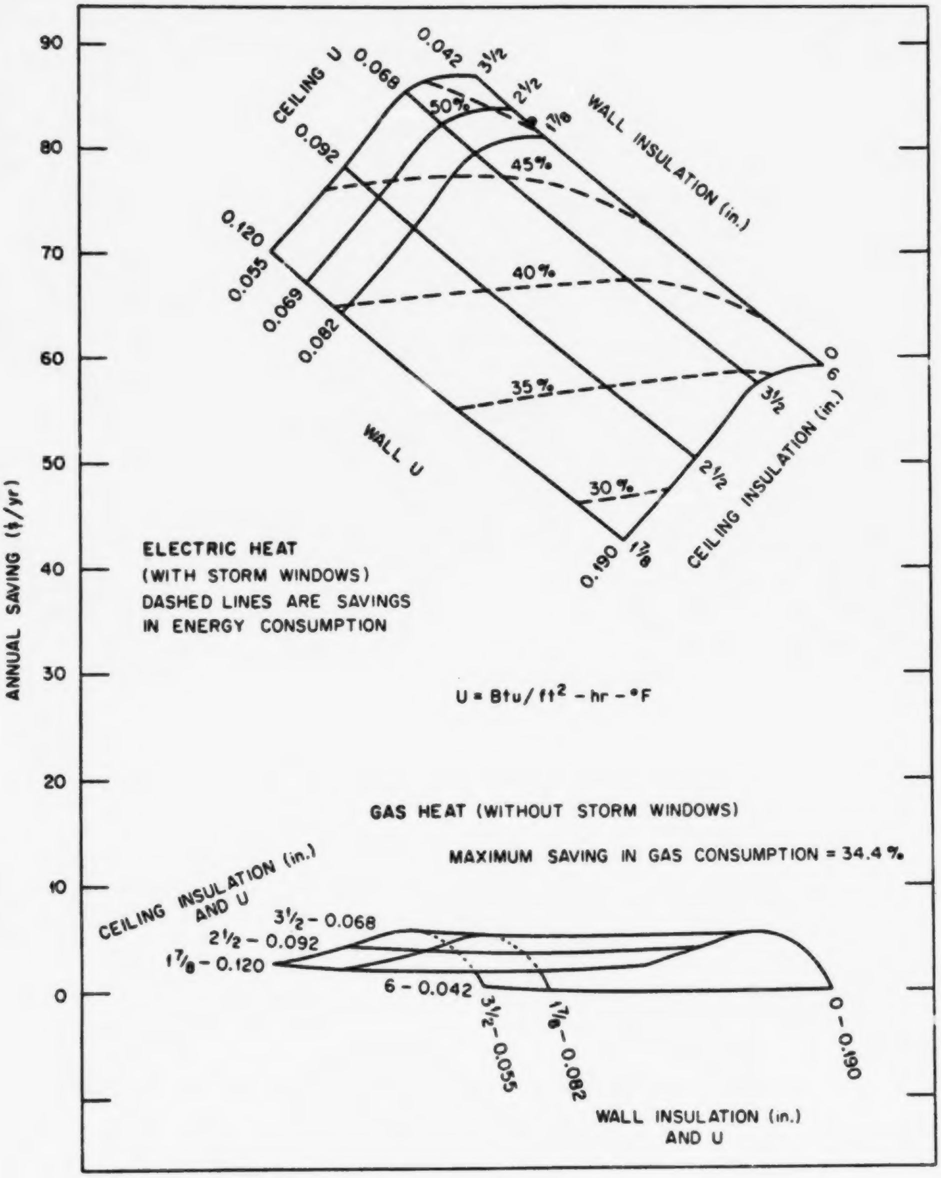
Fig. .2



FLOOR UNINSULATED (U=0.28)
WITH FOIL AND AIR GAP (U=0.093)
DEDUCT 22.7 MBtu/yr
$U = Btu/ft^2 - hr - °F$

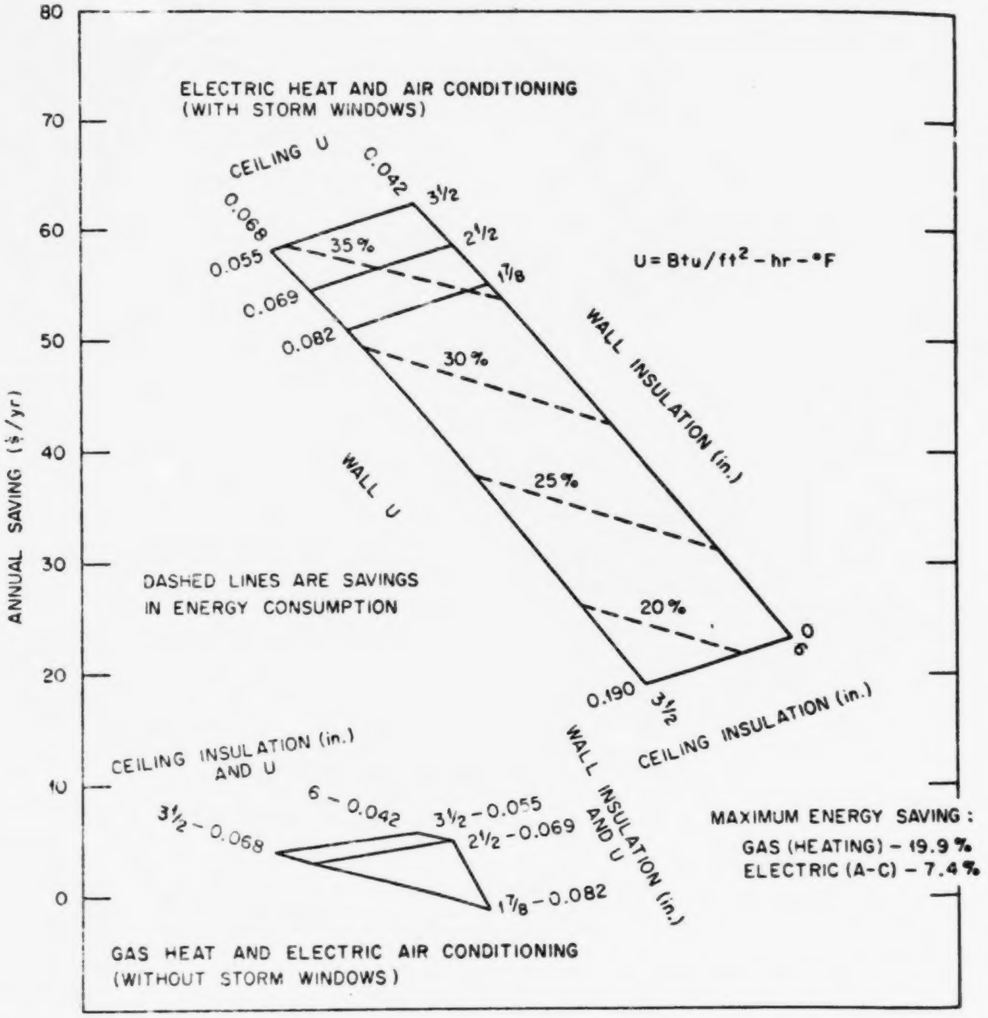
Annual Heat Loss: Minneapolis Residence.

Fig. 3



Annual Saving Due to Insulation, Atlanta Residence - Heating Only.

Fig. 4



Annual Saving Due to Insulation, Atlanta Residence – Heating and Air Conditioning.

Fig. 5

limits on its building and financing. These upper limits may be the main reason why there is little motive to include storm windows within the FHA appraisal, for instance, or to generally include the value of additional energy-saving investment within the value which the home-buyer might be expected to know about and pay for. In the absence of such knowledge, it is hardly surprising that there has been serious underinvestment in energy-saving alternatives. This has an optimistic side. Even without an increase in energy prices, owners can save money by buying more insulation, once they understand the options. Increases in energy prices are less likely to be a burden to owners than to goad them to invest in better insulation; it is likely that the end result will not merely be smaller fuel consumption, but also smaller fuel bills.

STRATEGY R-3: Remove Institutional Barriers, as in FHA Appraisal Rules.

To understand the kinds of market failure with which we must deal, consider just the case of storm windows which has already been alluded to, and which will be treated in more detail below. Nationally, storm windows will pay for themselves in about seven years, and many home owners find them a prudent investment. However, they are seldom installed as part of construction; and the vast majority of homes do not have them at all. Why? A major factor must be that many owners do not expect to own their present homes for that 7-year payout period (average duration of occupancy is about 3 years) and so make the rational choice of not buying storm windows. But why don't they assume they will recover much of the cost at the time of resale? Probably because as long as FHA regards the windows as movable, and refuses to include them in the appraisal, they simply don't have a significant value at resale.

STRATEGY R-4: Control Quality of Energy-Saving Installation.

Improper installation of insulation also results in some increase in energy consumption. For example, improper installation of vapor barriers can create conditions of conductive losses up to twice the value of properly insulated walls. Approximately 2 percent of heating and cooling losses are accounted for by exfiltration through walls. This exfiltration loss could be reduced by 50 percent if regulations were written and enforced to include quality of installation as well as quality of material. Enforcement and control of such regulations would of course be difficult, because insulation flaws are generally well and easily concealed. Code regulations might therefore be difficult to use as a control measure without corresponding modifications of building inspection practices which would discourage slip-shod construction techniques. Public concern over such practices seems to be rising; it is important that energy-awareness be included in this concern, in place of our historic view of energy as a cheap and abundant, hence negligible, factor.

Conductive heat loss through a typical exposed foundation area comprised of two feet of concrete block equals that of an eight foot insulated wall. The application of fibrous insulation on inner surfaces could result in as much as a 90 percent energy savings in this case.

Modifications to insure proper fitting of doors and window frames, and caulking of leaks, could also result in major reductions of infiltration losses. A reduction of infiltration to 100-200 cfm would cut heating and air conditioning consumption by 15 percent. A simple infiltration test could be made part of FHA-HUD mortgage code restrictions, limiting infiltration to this range.

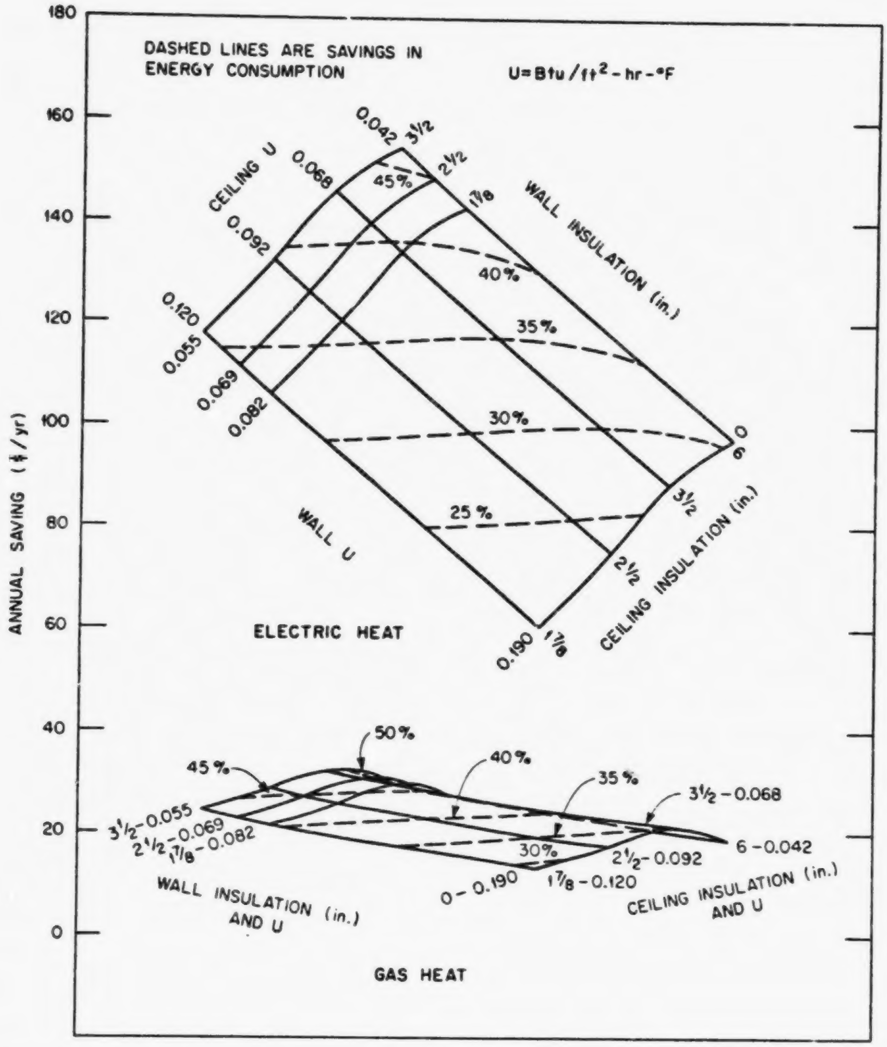
Conductive energy losses are seven times greater for aluminum, rather than wooden, window frames. For example, given a 10-square-foot window, edge loss will be about 25 percent of the window's total if the frame is aluminum versus 12 percent if the frame is wood.

The application of storm windows, on the average, results in an energy saving of 22 percent. Window loss accounts for approximately 60 percent of total residential energy consumption, and therefore the application of storm windows can be expected to result in approximately a 13 percent total household energy reduction. Figures 6-9 show possible energy savings from the use of increased insulation and storm windows.

Installation of attic fans designed to keep a constant flow of air through the attic space could result in a 15-40 percent reduction of heat gain through the ceiling areas and approximately a 2 percent reduction in energy use for cooling. Convective losses through open flues of fireplaces could be eliminated, with a 20 percent saving for such residences, if a visible indication were given when the flue was left open.

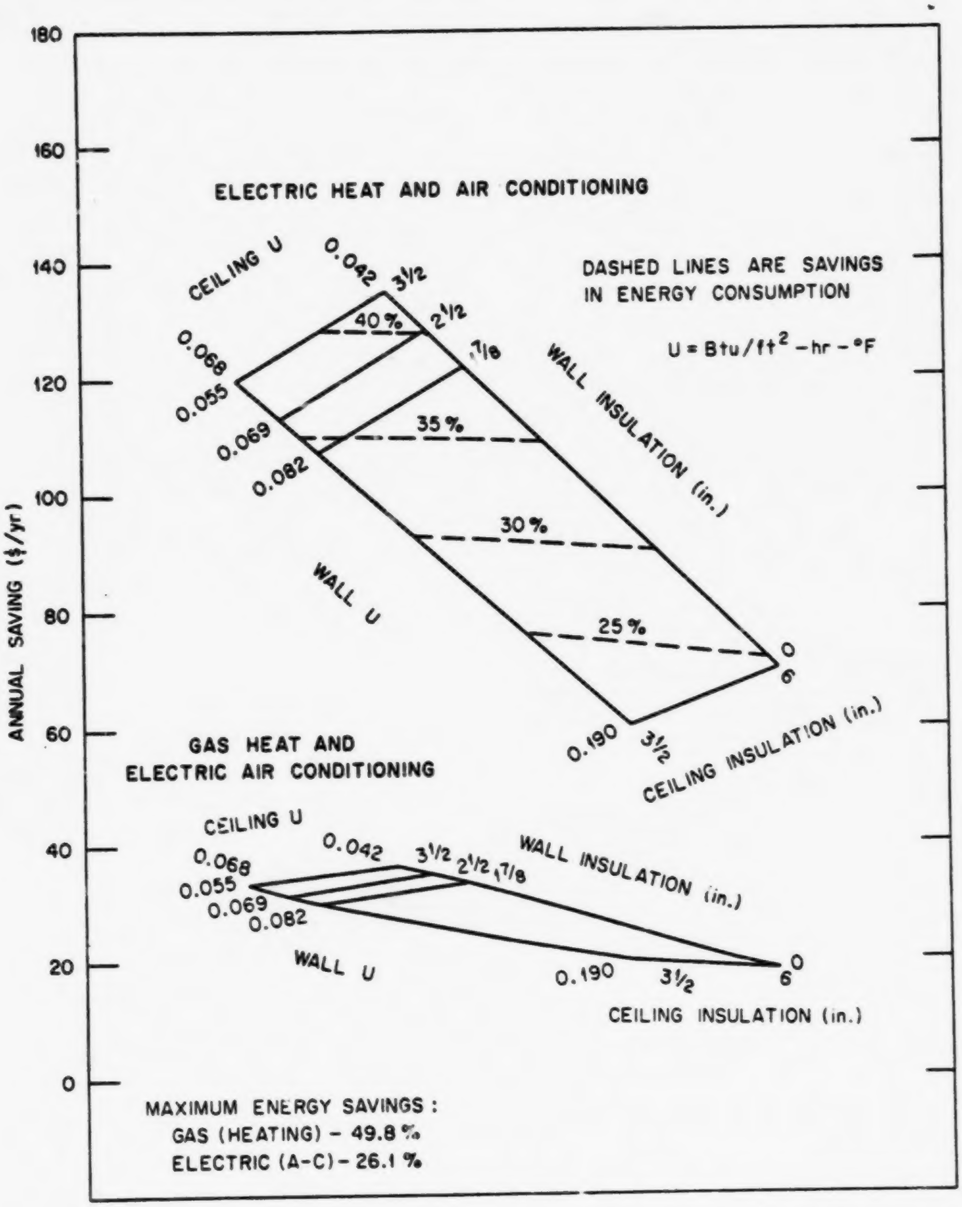
Heating and air conditioning account for a large portion of residential/commercial energy use (approximately 11.7 percent for households and 8.7 percent for commercial structures). The primary method of conserving energy centers around methods to improve efficiencies in furnaces themselves. A single heat removal alternative (known as a heat pipe refluxer system) could result in a 10 percent energy saving, and a combined system which would extract and reuse heat of vaporization would result in approximately a 28 percent energy saving. In addition, other modifications to conventional heating and cooling systems are presented in Table XI along with the annual fuel consumption of each alternative.

An open-air-cycle device used to compare outside air enthalpy with return air enthalpy, and equipped with an outside vent, could save approximately 14 percent of the energy used for air conditioning.



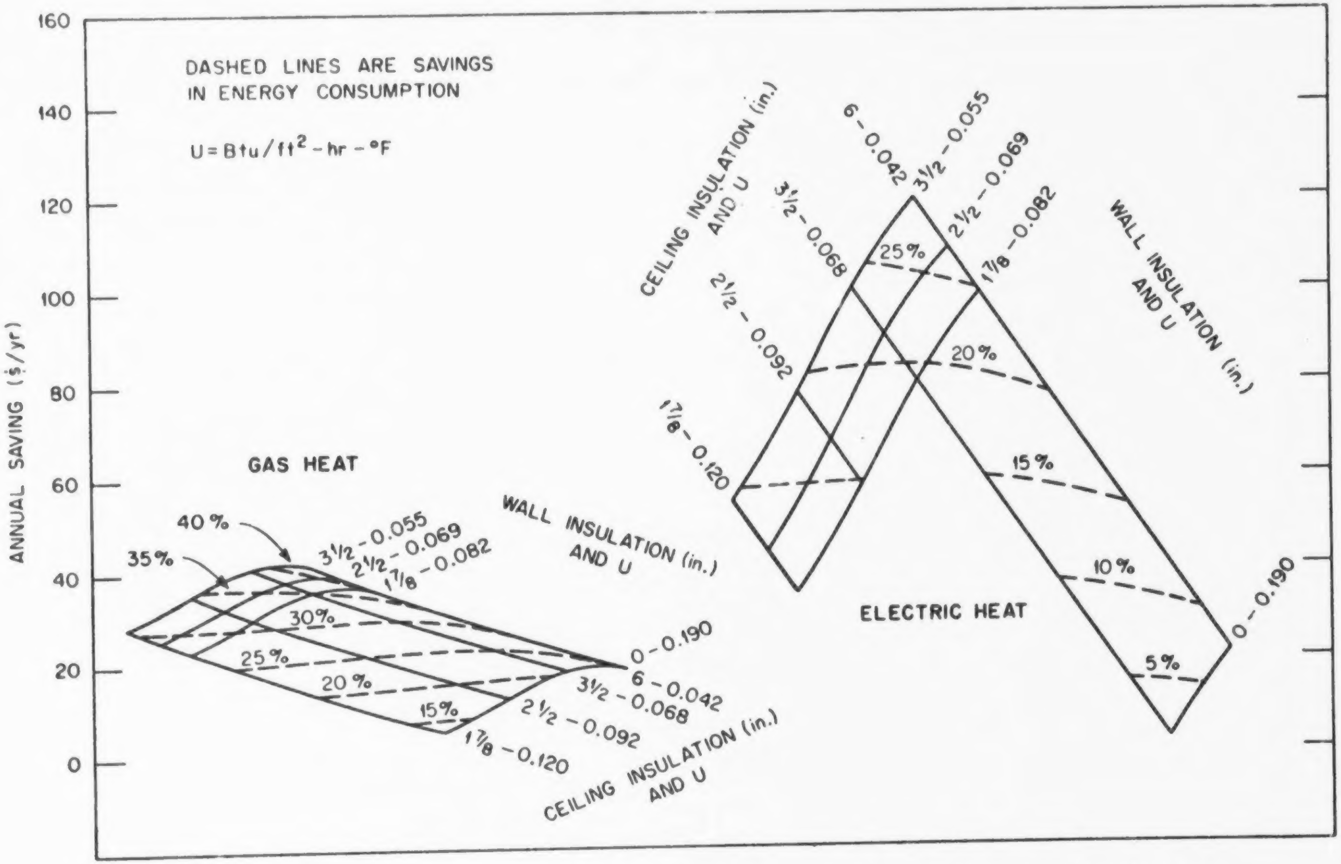
Annual Savings Due to Insulation and Storm Windows, New York Residence - Heating Only.

Fig. 6



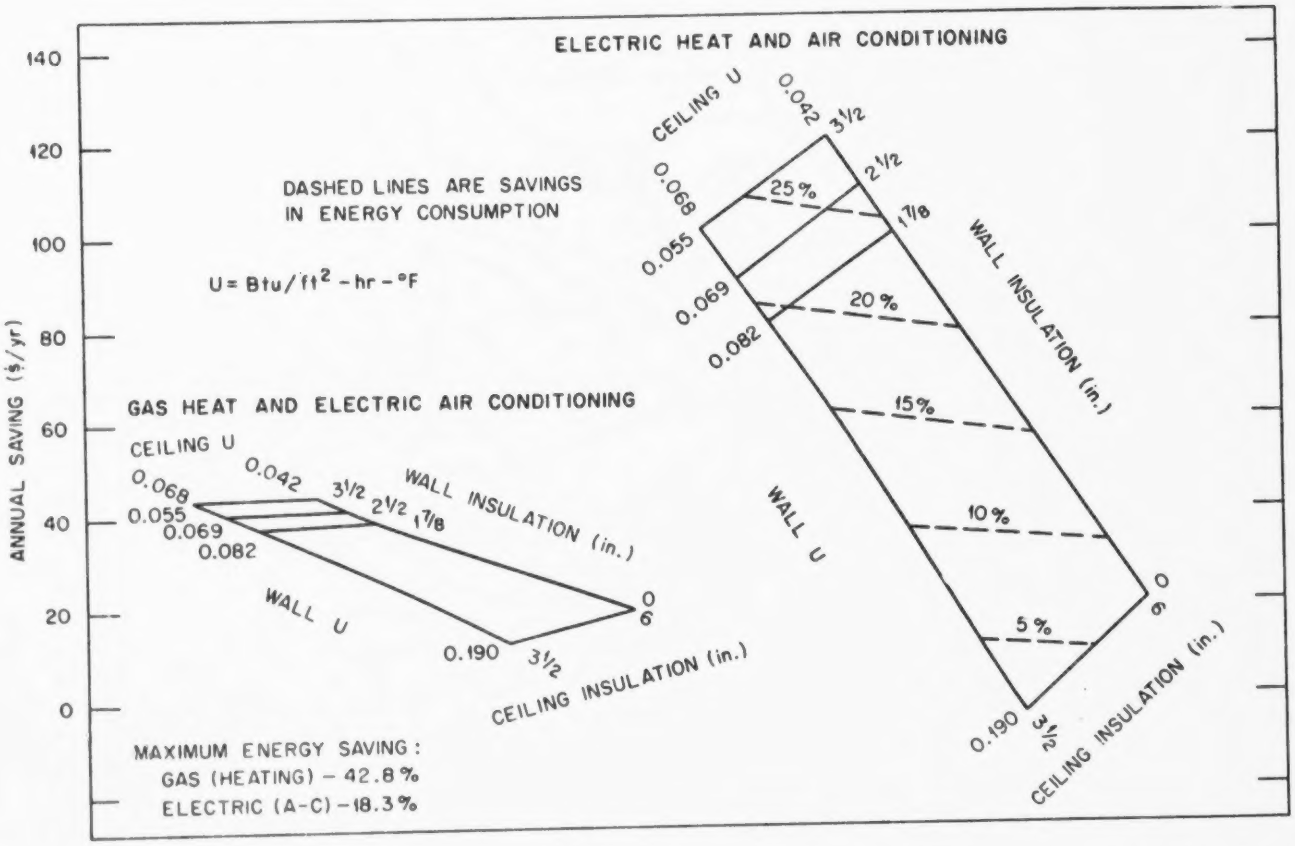
Annual Saving Due to Insulation and Storm Windows, New York Residence – Heating and Air Conditioning.

Fig. 7



Annual Savings Due to Insulation and Storm Windows, Minneapolis Residence – Heating Only.

Fig. 8



Annual Saving Due to Insulation and Storm Windows, Minneapolis Residence – Heating and Air Conditioning.

Fig. 9

TABLE XI - FUEL CONSUMPTION OF ALTERNATIVE SYSTEMS FOR HEATING AND AIR CONDITIONING

	Ventilation Rate	Annual Fuel Consumption			
SYSTEM*	(CFM)	Therms**		kWh***	
Conventional	250	1450	(100.%)	2800	(100.%)
" with run around coils	250	1150	(79.3%)	2440	(87.3%)
" with heat pipe	250	1090	(75.2%)	2420	(86.5%)
" with heat exchange wheel	250	1000	(69.0%)	2330	(83.3%)
Variable Volume	72	1025	(70.7%)	2350	(84.0%)
" with run around coils	72	935	(64.4%)	2260	(80.7%)
" with heat pipe	72	910	(62.7%)	2240	(80.0%)
" with heat exchange wheel	72	898	(61.4%)	2220	(79.3%)

* Assumed conditions: 6600 degree-days heating,
1000 full load hours cooling at 1.4 kW/ton.

** One therm = 100,000 BTU

*** One kWh = 3412.8 BTU

STRATEGY R-5: Encourage Energy-Awareness in Appliance Choice.

A major wastage occurs in the pilot light of gas appliances; their continuous consumption for a typical house can be about 15,000 cubic feet (or 14 million BTU) per year, or more than half the annual energy required for hot water heating, and 4 percent of the total gas needs of a gas-heated residence. Range pilots use about 150 BTU/hour each; pilots on furnaces, hot water heaters, dryers, and some ovens consume 400 BTU/hour each. As substitutes, electric igniters have been developed, but are generally rated for 25,000 cycles -- too short a life for a furnace or hot water heater, but sufficient for gas dryers and ovens. They are coming into general use in dryers, simply because a continuous pilot uses almost half the dryer's lifetime energy needs.

Outside gas lights consume approximately 18,000 cubic feet per year, about 5 percent of household gas use. These are not metered; since they are left in continuous operation, they are paid for by a fixed charge. If they were metered, there would be short-run incentives to reduce gas use by turning them off; but there might be a greater risk associated with leaking lamps. Such lamps are in many places a recent suburban phenomenon, somewhere between a quiet amenity and conspicuous consumption. As such, their economic utility is hard to measure. In many areas, gas suppliers no longer provide these lamps to their customers, but we know of no cases where customers have been assisted to convert the lamps to electricity to save the gas light's fixed charge. As prices rise, it is important that consumers not be locked in this specific consumption choice.

For appliances generally, their initial selection has a significant impact on their lifetime energy requirements. For instance, the least expensive version of an air conditioner will usually require twice as much electrical energy per unit of cooling load (compared to more expensive models) due to reductions in condenser and fan size. Regulations specifying certain minimum efficiency levels could result in perhaps a 40 percent energy saving over the life of such appliances, with resulting savings in operating costs.

Of course, it would not be economically efficient to require a high level of energy-efficiency regardless of cost. An appliance which will be used very lightly by its owner would better conserve resources by being cheap, rather than efficient; but it is important that heavily-used appliances be chosen for efficiency rather than initial cost. To the degree that appliances have either a fixed duty cycle in normal use, or have a normal lifetime measured in duty cycles rather than years, one way to induce energy-conserving choices is by a fixed energy tax to be paid when the appliance is purchased; but a better way might be to label the appliance by its expected energy consumption, to help the consumer choose wisely on the basis of energy prices.

AN EXAMPLE

The aggregate energy-saving opportunities can best be illustrated by presenting a characteristic house which contains a number of the above improvements. This example will have the advantage of demonstrating the actual energy savings possible under alternative parameters for a residential structure. Hittman Associates, Inc., has specified and evaluated several levels of such alternatives. Table XII describes a Characteristic House and two design variations of it. Table XIII shows the potential energy savings for winter heating and summer cooling of the Characteristic House, and demonstrates that there are substantial savings possible through the application of storm windows, window area reduction, recovery of furnace heat, and the use of high performance air conditioning units.

Table XIV shows the yearly energy use, energy saving, and monetary saving, both at the basic-need ("House") level and at the supplier ("Plant") level, of the Characteristic House and for Designs I and II. It will be noticed that the house has a yearly heating bill of $154, the national average for a house this size and design. Obviously the heating bill and the potential savings will both be larger for a house in a colder climate; on the other hand, such a house would generally already be better insulated than the national-average house. Detailed research is needed on the geographic variations in potential energy savings and the economics thereof. However, it seems reasonable to estimate that the magnitude of savings indicated here is broadly representative of the nation, and that percentage increases in fuel costs will produce corresponding percentage changes in the monetary savings associated with the energy savings shown.

It was suggested above that a short-run approach to encouraging the adoption of such energy-saving changes in the residential/commercial sector would be to grant subsidies to builders, either directly or through tax credits or deductions. The magnitude of this energy-conserving subsidy would of course depend on a multitude of characteristics of the structure, and on the exact form that any such subsidy might take. For example, in comparing the effect of a tax deduction to that of a tax credit, both in the amount of the subsidized improvement, the tax credit will be more costly to the government and more influential to the recipient because it is a 100% compensation; the deduction is only a compensation at the marginal tax rate of the recipient, and it is therefore less costly, but its effect varies with the tax bracket of the recipient. (The approach of using deductions is partly premised on the assumption that marginal tax rates represent varying levels of marginal utility of money; but few economists still believe this is a valid premise.)

TABLE XII - CHARACTERISTIC AND DESIGN HOUSE DESCRIPTIONS

CHARACTERISTIC HOUSE

The Characteristic House is a two-story wood frame house, facing north on an unshaded lot, with 1500 square feet of finished space, occupied by two adults and two children. Exterior walls are wood shiplap over 1/2" plywood, R-7 batting, and 1/2" drywall. It has 5" blown-in ceiling insulation below a ventilated unheated attic, with white asphalt shingle roof; a full unfinished basement, and an attached enclosed unheated garage on slab. Windows cover 180 square feet, and are A1 casement type, without storm windows or awnings, 70% draped and 20% shaded. The 3 doors cover 60 square feet, and are wood panel with 6x12 glass pane; patio and storm doors are 40 square feet each, single-pane glass. The house has natural gas forced air heat and electric central air conditioning.

DESIGN I

The Design I House is the same as the Characteristic House except for addition of storm windows, and wall construction of insulated aluminum siding over cinder block, R-7 studded insulation, and 1/2" dry wall.

DESIGN II

The Design II House is the same as the Design I House except that window area is reduced by 25 percent, and the lot provides 20 percent shading of the house.

TABLE XIII - SAVINGS FROM MODIFICATION OF CHARACTERISTIC DESIG

	..WINTER LOAD..		..SUMMER LOAD..	
LOAD or MOD	PERCENT SAVED	MBTU SAVED	PERCENT SAVED	MBTU SAVED
Furnace Reference Load	100.0	101.4		
Air Conditioner Load*			100.0	10.8
Furnace Recovery	27.9	28.3		
High Performance Unit**			33.3	3.6
Furnace Pilot Elimination***	3.4	3.5		
Open Air Cycle			8.3	1.0
Storm Windows	15.8	16.0	8.1	.9
25% Window Area Reduction	19.1	19.4	9.5	1.0
Cinder Block Insulation	7.1	7.2	.6	.1
High Capacity Wall	2.6	2.6	.8	.1
Sealed Furnace Air Supply	4.6	4.7		
Sealed Hot Water Air Supply	1.7	1.7	1.9	.2
Clothes Dryer Recovery	2.4	2.4		
Double Door Design	1.6	1.5	3.8	.4
Revolving Door Design	2.6	2.7	6.9	.7
Ducted Oven Design			1.9	.2
Ducted Refrigerator			7.0	.8
Attic Ventilation			.5	.1

* - Based on 8.0 BTU/watt-hr performance
** - Based on 12.0 BTU/watt-hr performance
*** - Based on a 1000 BTU/hr pilot light

TABLE XIV - HOUSE & EQUIPMENT SAVINGS WITH DESIGN I & II, CONCEPTS

HOUSE:	.....HEATING.....			.....COOLING.....			......TOTAL......		
	LOAD MBTU	SAVE MBTU	SAVE PCT.	LOAD MBTU	SAVE MBTU	SAVE PCT.	LOAD MBTU	SAVE MBTU	SAVE PCT.
CHAR. HOUSE	71.0	-	--	28.2	-	—	99.2	-	—
DESIGN I	52.9	18.0	25	25.4	2.8	10	78.3	20.8	21
DESIGN II	39.3	31.7	45	24.8	3.4	12	64.1	35.1	36
II+Concepts	32.3	38.8	55	18.7	9.5	34	51.0	48.3	49

- -

PLANT:	.....HEATING.....			.....COOLING.....			......TOTAL......		
	LOAD MBTU	SAVE MBTU	SAVE PCT.	LOAD MBTU	SAVE MBTU	SAVE PCT.	LOAD MBTU	SAVE MBTU	SAVE PCT.
CHAR. HOUSE	104.4	-	--	38.5	-	—	142.9	-	—
DESIGN I	77.8	26.6	25	34.7	3.8	10	112.5	30.4	21
DESIGN II	57.6	46.5	45	33.7	4.8	12	91.6	51.3	37
II+Concepts	37.0	67.4	65	17.0	21.5	56	54.0	88.9	64

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COSTS:	.....HEATING.....			.....COOLING.....			......TOTAL......		
	COST $$	SAVE $$	SAVE PCT.	COST $$	SAVE $$	SAVE PCT.	COST $$	SAVE $$	SAVE PCT.
CHAR. HOUSE	154	0	0	82	0	0	236	0	0
DESIGN I	115	39	25	74	8	9	189	47	20
DESIGN II	93	62	40	73	9	11	166	71	30
II+Concepts	55	100	64	56	26	32	111	126	53

Source: Hittman Associates, "Residential Energy Consumption Briefing"

It is possible to illustrate the workings of a tax-based subsidy, assuming that the energy-saving modifications of the Design II house are to be encouraged. Hittman Corporation has determined that the design changes suggested for the characteristic house described above would not exceed a cost of $2000. Suppose that all the design changes have an amortization life of 30 years, and that the $2000 would add $14/month or $168/year to the payments on a 30-year, 7% mortgage. Table XIV indicated that the changes would produce a fuel saving of $126/year. The difference is about $42/year, or the payment on $500 capital. It is possible that some home owners would find such energy saving to have non-monetary benefits (such as a more draft-free and comfortable setting) which are worth this much to them; but in general, and for analytic purposes, we will assume that $42/year or $500 initially is an adequate measure of the difference between energy conservation which society desires and the private cost of achieving that conservation.

A number of rational policy options are open to society on the basis of these numbers. The first of these might be to take no action, on the assumption that the benefits of insulation are lower than its cost. The second option might be to determine what smaller amount of insulation would be cheaper than the benefits it would produce. A third option (and the one which seems most valid in today's market) would be to question whether the "benefits" are accurately measured by the present price of the energy which is being saved; in this example, a 33% increase in the price of fuel would make the conservation package economical (though not necessarily the optimum amount of saving), by raising the value of saved fuel to $168. A fourth option would be to make the conservation package economical to owners, without necessarily raising fuel prices; this might be done by offering a tax credit of $500 to all owners, or a tax deduction of $2000 to owners who are in the 25% bracket.

Consider the relative equity of the third and fourth options. The only real difference between them is that the fourth option is an expense to all taxpayers through the government subsidy which must be paid; it also preserves exactly the current costs to owners, whether they insulate or not. This would be the preferred solution if there were a reason for thinking that current energy prices represented full energy costs, and that it was in the public good to force the expenditure for insulation. (But if this were true, why would society choose to spend $168 for insulation-resources to save only $126 of energy-resources?) Conversely, the third option places a new burden of increased energy costs on owners, rather than taxpayers in general; after the stated increase, they are simply indifferent between paying more for energy and paying more for insulation. All things considered, they would prefer to pay less, rather than more. But this misses the point, for the real policy question is not whether anyone pays more, but whether the payment is made by the users of the energy or by the general taxpayer. The difference between these two will be analyzed in terms of efficiency in a moment; but it must be remembered that the home owner who is hurt most by a fuel-price increase will be precisely the individual who has been reaping the greatest hidden subsidy in artificially low fuel prices until now. In other words, we are not discussing an arbitrary tax on fuel; instead, we are talking about the price increases which are going to happen as the scarcity and the environmental consequences of energy use begin to be paid, rather than ignored. Those who are now using the most fuel also benefit most from ignoring these consequences; they will be hurt the most by price increases which goad them to conservation measures; but this "hurt" is relative to current benefits, and is not an argument for artificially maintaining those selective benefits forever. (This point has already been made, in the "Overview", with respect to certain industrial users of electricity; it is not confined to either industrial or residential users, but is a fact of such significance as to warrant repetition.)

The issue of economic efficiency centers around which option will achieve the greatest saving of energy at the least total cost. If installation of energy-saving devices were an end in itself, then option 4 (direct subsidy, via tax deductions or credits) would be efficient in the sense that payment would be made if and only if the devices were actually installed. However, our objective is not the devices; they are only a means toward the end of energy conservation. The means (in this case, devices) should be used in varying degrees, as a function of the kinds of climate, energy-use pattern, and other variations among individual users. Storm windows might, for instance, be far more valuable to a house which is fully heated and air-conditioned, than to a comparable house occupied by a family which prefers fresh air year-round. It is conceptually possible to define, in full detail, all the variations which contribute to reaching an optimum solution. However, it is legislatively and administratively impossible for government to become as meddlesome as these details would require. For this reason, it is preferable to move as far as possible toward option 3, where we price the end (energy use) itself, inform people of the options and remove present barriers to their making the choices which promote conservation, and then allow each of the builders and owners to make economically rational choices to save energy to exactly the degree that will save money.

Under such an option, consumers ought (in theory, given a smoothly functioning market) to make the same set of conservation choices that a central authority would make for them, if it had sufficient information. Before advocating either option, one ought to know just what those choices would be and how much energy might be saved. The data to allow such estimation is not available, however.

Research is underway on such topics as the geographic and climatic characteristics of various classes of dwelling, and the relative costs and benefits of insulating old vs. new, or single-family vs. multi-family, dwellings. (For older units, or for single-family units, both the costs and the savings are considerably larger; the issue is whether specific national policies ought to focus first on one or another subset.) Such detailed variations can not be considered within this report, however: data is not yet available.

To derive some national estimates for this report, we have taken the energy-savings estimate of 89 MBTU/year from Table XIV, and the Hittman estimate of $2000/dwelling for the added insulation and savings concepts for a single-family dwelling. A 50% premium was added to this cost for retro-fitting existing units; a 25% reduction was made for economies of scale in multi-family units. This approach leads to the following estimates:

For all new residential construction through 1990, additional capital costs for energy conservation would be $60 billion; by 1990, we would be saving about 2.7 Quads per year. Non-market encouragement of this strategy would be through direct regulation or through tax-based subsidies.

For all existing residential construction, additional capital costs would be about $160 billion, and would save about 4.5 Quads per year. Non-market encouragement of this strategy might be through loans or tax-based subsidies; in addition, careful attention should be given to such non-market forces as the appraisal rules for such investments, and the possibility of rating or otherwise standardizing the energy-use characteristics of dwellings and appliances.

Of the 2.4 Quads attributed (in Section III.A above) to electrical rate revision, only 0.8 Quads will be included here; of the rest, .8 Quads would overlap the Hittman savings in uses where there is no alternative to electricity, and .8 Quads would be gross electrical savings, but canceled by increases in use of alternative energy sources for the same purpose.

In the commercial sector, potential savings seem comparable; but much energy waste occurs for non-market reasons such as the aesthetics of glass or aluminum siding. Additional technologies, such as current heat pumps and future total-energy systems, are applicable; but it is not yet possible to estimate the costs or savings of these.

SECTION IV

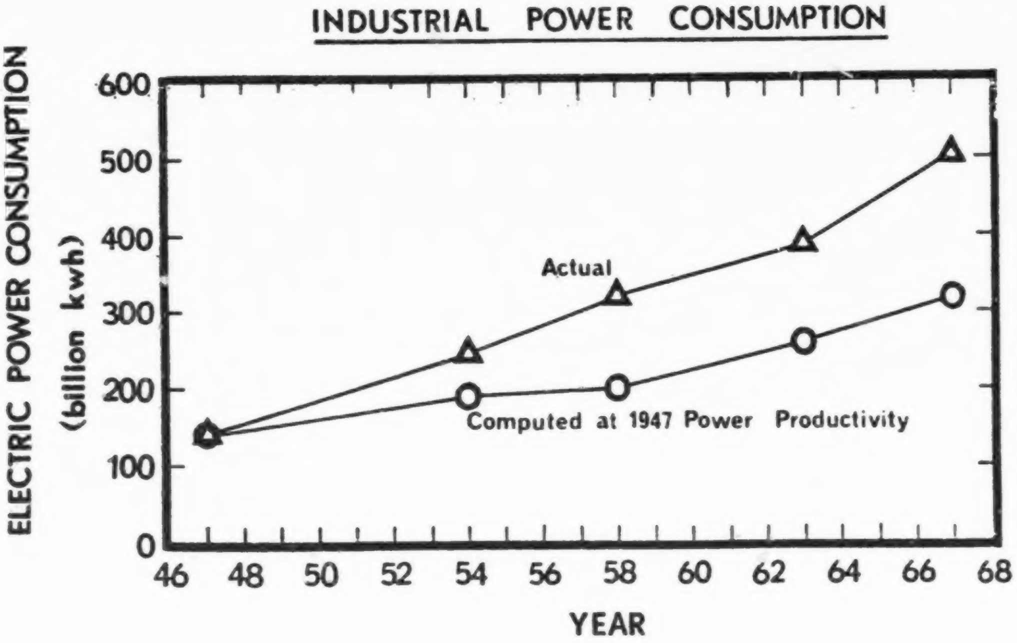
THE INDUSTRIAL SECTOR

Industrial end-use energy consumption accounted for 42.3% of total energy consumption, and 41.5% of total electrical energy consumption, in 1970. By 1990, this sector is expected to use about 50%, or 70 Quads, of the nation's energy. Though very little research or data on industrial energy conservation is available, large savings seem possible if energy conservation measures are implemented.

As elsewhere in this report, our concern is not for eliminating activities which are heavy users of energy, or otherwise constricting the economy and its growth. Rather, our concern is for finding activities which can reduce their use of energy, possibly saving money in the process. It is often assumed that industry is sufficiently cost conscious that it is already practicing all feasible energy-saving methods. But cost awareness need not imply such practices, for two reasons. First, there are many institutions and market distortions that interfere with saving energy. Second, it is perfectly possible for a price increase of, say, 10% to make economic some processes, techniques, and devices that would save a much larger fraction of energy, say 20% or 30%. To determine whether this is so requires a very close scrutiny of where energy is used, how much it costs in each use, and how much it would cost to save some of the energy in those uses. It must be remembered that for twenty or thirty years the nation has treated energy as a commodity that should be made ever cheaper and more abundant; in the process, environmental costs have been ignored. It would be astonishing if industry had not, in this time, used more energy than now seems desirable in the light of environmental concerns. Our question is this: which energy is so used, and how much of it can be saved?

Industrial use of electric power has increased exponentially -- doubling about every fourteen years. In recent years, the trend has been for electric power consumption to increase at a rate in excess of the rate of increase in the economic benefits yielded by industrial production. A way to visualize this effect is to compute how electric power would have increased after 1947 if power productivity had remained constant rather than declining after that year. Figure 10 shows that if the technological transformation in the use of electric power which took place in U. S. industry after 1947 had not occurred, industrial power consumption in 1969 would have been reduced by about 35 percent.

Because power productivity has declined so much since 1947, it becomes important to ask whether this trend can be reversed, and what the likely consequences of such a reversal would be. This requires a



$$\text{Computed Power Consumption For year X} = \frac{\text{1947 Power Consumption} \times \text{Value added for year X}}{\text{1947 Value Added}}$$

FIGURE 10

more detailed analysis of the reasons for the declining trend, and this in turn requires an examination of different industrial sectors.

Energy consumption by industries with very low power productivities (e.g., petroleum, chemicals, primary metals and and coal products) has increased more rapidly than consumption by those industries with higher power productivities. The tendency has been for industries which operate at low power productivities to displace industries which operate at high power productivities. Thus, production of nonferrous metals, especially aluminum, has grown much faster than steel production, due to the replacement of steel (and lumber) products by aluminum ones. The growth of the chemical industry is based on the displacement of a number of natural products which involve very little power consumption (e.g., cotton, wool, lumber, and soap) by synthetic chemical products (man-made fibers, plastics, detergents.)

Were these displacements necessary, perhaps due to the depletion of raw materials? One must conclude that in general, the displacements were not forced. There is no evidence that aluminum has replaced steel because the latter is in short supply, or that detergents have replaced soap because we have run out of saponifiable fat. If they were not forced, then these displacements which have lowered the efficiency of industrial energy consumption are, at least in principle, reversible. Major savings in industrial energy consumption could be achieved by reversing the trends of the post-WWII period.

Such a reversal does not, of course, mean a return to 1947 technology and products. The prewar trend had historically (as the Presidential Energy Message noted in 1971) been a trend of increasing efficiency: newer and better products, many of them energy intensive, were constantly introduced, but so was growth in the productivity of those products, as well as the efficiency of other energy-saving methods, so that the net effect kept productivity rising faster than energy use. Since 1947 (and probably because of war-related easier access to energy sources) this has not been true. There is every reason to assume that we need only use energy-saving methods we have been ignoring; we need not suddenly abandon the energy-using products we have grown accustomed to.

But even among those products, it is easy to identify specific uses in which the new and energy-intensive product has only a slight advantage over the product it replaced. (The search for a better shoe material than second-hand cow coverings is just one example.) Such uses of such products may well have no advantage at all once all the costs (both the energy-cost of the substitute shoe material, and the full social costs of disposing of surplus cowhides, in our example) are taken into account. In such a case, one can hardly argue that there is real hardship in forfeiting that use of that energy-intensive product. Where there is a genuine advantage, the market will cheerfully make a place for the new product at a higher price; we are focusing on those places where the energy-intensive product competes only because the environmental costs of energy are ignored.

Unlike the residential and transportation sectors, where the largest uses of energy are fairly homogeneous activities that admit of simple aggregation of basic refinements, industrial energy use consists of a vast array of activities and energy uses. Some of these, like lighting and process steam, are areas where a single change might apply to many industries; others, like electricity for aluminum extraction, are highly industry-specific; still others, like the production of aluminum for office sheathing, are inter-industry in nature. There is no realistic breakdown of categories of use within plants or industries. An inter-industry or input-output table of energy throughputs could be useful here -- except that it would not accomodate the process changes that are basic to a dynamic economy.

There have been numerous recommendations for standards, regulations, and consumer information to promote energy conservation in the residential and transportation sectors. In contrast, it seems to be generally assumed that industry responds to consumer needs in its production choices, and is sufficiently well-informed and cost-conscious to be saving energy in its production methods; therefore not much more energy can be saved by industry. For instance, OEP suggests (Table V) only 15%-20% savings possible by industry in 1990, compared with 25%-30% for other sectors.

Such an assumption begs the vital question of whether industry gets correct price signals, and passes them on to its consumers. The "cheap energy" emphasis of government policy for the last generation must bear the blame for the fact that these signals presently under-value energy, and thus promote its waste in myriad ways. The dynamics of industry and the market offer many ways for major savings to occur, given that prices begin to reflect social costs.

We will now sample some of the areas of potential energy savings. Before doing so, we make a simple point that will be elaborated at the end of this section: most of industry's projected 1990 "energy needs" will, in 1990, be from capital stock that does not now exist, and is not even on the drawing boards. As we survey the energy wastages to be found in current industial practice, we must constantly ask ourselves whether all the new investments should be made with a similar undervaluation of energy.

MARKET STRATEGIES

As was the case in the residential/commercial sector, primary reliance for achieving the reversal of the above trends in industrial energy consumption should be placed on the functioning of a rational market for industrial energy. The primary strategy to be used in attaining this goal is, therefore, a revision of energy prices and rate structures.

As with the residential/commercial sectors, we first present a discussion of the potential energy savings to be realized by price and price structure revisions for electrical energy. We present this analysis only for electric energy, because of constraints of time and data availability. Similar effects should be expected if similar revisions in the price of other forms of energy are made.

While the National Weighted Average bill for industrial consumption (Ref.9,pg.xxvi) shows average charges of 1.75c/kWh in 1970, the privately owned utilities reported an average revenue of only 1.02c/kWh from their industrial customers (Ref.10), and the publicly owned utilities received only 1.17c/kWh from their commercial and industrial customers combined (Ref.11). This reported revenue is well below the lowest reported marginal rate; it is not possible to base a meaningful calculation of actual marginal rates on these numbers, or on the details presently reported for individual companies.

Any given rate structure can be revised so that customers in a particular "block" of the rate schedule pay the same total bill that they pay now, and the utility receives the same revenues as it does now, but the marginal rate being charged is higher than at present. This is the essence of "block rate revision" proposals. It has nothing to do with charging more money for present electrical consumption, but only with setting the rate so that more money would be associated with using (or conserving) added electricity. The first indirect effect of this change would be that users would find ways to save some electricity, so that the utilities would in fact sell less and have smaller revenues (and costs); but to a first approximation, we are trying only to change the price of marginal units of consumption, not transfer money from industry or utility to residences.

To estimate the effects of such a block rate revision, it is essential to have some detailed knowledge of the price elasticity of industrial customers, and of the amount of electricity that is now being purchased by users in each of the blocks of the present rate structure. This is critical data which is not presently available, mainly because of disclosure provisions. (Consumption and costs for the largest users would stand out, statistically, and reveal specific firms.)

The best we could estimate was to assume 11% marginal rate increases (the same as for the residential sector, and surely very conservative for the industrial sector where block rates and discounts are widespread) with an elasticity of -1.7, to obtain a 19% conservation of electrical energy. This seems certain to be a very moderate estimate, given the specific bias (cited in the Overview) favoring lowest prices for most-elastic customers.

It must be remembered that the calculated elasticity is based on known responses to price, with current technology. The following discussion of specific energy-saving possibilities points to additional methods for saving energy, after price changes have taken effect.

NON-MARKET STRATEGIES

As in the case of the residential/commercial sector, there are economic, social, and political constraints which might prevent, at least temporarily, the efficient and effective functioning of market mechanisms in the demand for industrial energy. For this reason it may be necessary to supplement the primary strategy suggested above with interim strategies: strategies which are not intended to themselves become institutionalized barriers to a freely operating energy market, but rather only a temporary guidance mechanism to be used to re-orient energy decisions towards an economically and socially rational market framework.

It must be noted that because of the myriad of uses that energy finds in the thousands of energy-using industrial operations, it is impossible to generalize on how efficiently energy is being consumed at present. Because of this, potential energy savings from industrial demand reduction can be estimated only roughly at this point. Considerably more research is needed to determine which sectors are using how much energy of each form and price for what purpose, or by what process.

In the absence of such research and such detailed knowledge, there still appear to be two broadly applicable non-market strategies to help energy to be conserved in the industrial sector. One strategy consists of establishing certain minimum insulation requirements for specific applications to industrial capital equipment. The other is the use of incentive mechanisms such as tax credits and/or penalties to encourage investment in energy-saving capital equipment.

These strategies, it must remembered, should be designed only as temporary mechanisms and only implemented in those industrial areas in which the market will not provide sufficient stimulus to produce an efficient degree of energy conservation. To determine where and when this is so, additional research is also needed on specific examples of market failure. Some of these examples will be discussed in the next section.

The following section presents a brief summary of industrial energy use trends, technological potentials for reversing these trends, and estimated benefits of energy-saving technology.

ENERGY-SAVING TECHNOLOGY AND BENEFITS

Most of the technological aspects of energy conservation center around the selection of specific materials and the use of energy in the production of such materials. That is, we can conserve industrial energy either by producing materials in a more energy-efficient manner, or by choosing more energy-efficient materials for use in final products. Both aspects of conservation are discussed in this section.

STRATEGY I-1: Encourage Recycling of Selected Materials.

In many cases, the biggest energy conservation can be achieved at the very start, by recycling raw materials rather than extracting them from raw mineral resources. Selectivity is needed here; this report is not directly concerned either with mineral conservation or with recycling in general, and it must be noted that some recycling can use more energy and other resources than virgin processing. The Oak Ridge National Laboratory studied the energy equivalents for the production of metals and compared them in terms of equivalent energy inputs. Their study indicates, for instance, that poorer grade bauxite ores used to produce aluminum do not require much additional energy, but that when clays and anorthocite are used, energy requirements are increased appreciably. Recycling of copper scrap will use much less energy (even where the copper is impure) than producing copper from ores. As poorer grades of copper and titanium ores must be used, energy consumption will increase appreciably. Recycling titanium also requires much less energy than producing it from ores. Table XV summarizes the energy requirements for the production and recycling of various metals.

STRATEGY I-2: Promote Energy-Saving Materials in Manufacturing.

Table XVI summarizes some computations of the power required to mine and manufacture the metals used in the production of an average passenger automobile. The table indicates that the chief reason for the increase in power required to produce the vehicle is the sharp increase in the use of aluminum which has replaced steel in certain car parts, especially the engine, trim, bumpers, and auxiliary hardware. This trend is reversible. An estimate of the energy saving which might be possible by sharply reducing the aluminum content of the automobile appears as Modification I in Table XVI. Modification I simply assumes a 90% replacement of the vehicle's aluminum by an equal volume of steel. Modification II reduces the metal content of the automobile, and was achieved by reducing the size of the car. The result is that less than half of present energy requirements is still needed after Modification II is implemented. Modification I would save 1.6% of industrial, or 75% of national, total energy consumption; Modification II would save 2.0% of industrial or .92% of national consumption. While these savings are small in themselves, they are indicative of savings available from energy-saving efforts across the whole metal-manufacturing sector.

TABLE XV - ENERGY FOR PRODUCTION & RECYCLING OF METALS

METAL	ORE OR MAIN SOURCE	ENERGY (kWh/ton)
Magnesium	Sea Water	90,930
Aluminum	Bauxite	51,470 - 59,540
	Clays	65,972
	Anorthosite	72,360
Iron	High Grade Hematite	3,180
	Magnetic Taconites	3,560
	Iron Laterites	5,180
Copper	1% Sulfide Ore	13,530
	0.3% Sulfide Ore	24,760
	98% Cu Scrap Recycle	590
	Impure Cu Scrap Recycle	1,560
Titanium	High Grade Rutile	126,280
	Ilmenite-bearing Mineral(sands,rocks)	150,120-157,080
	High Grade Ti Soils	206,750
	Ti Scrap Recycle	39,000

Source: AAAS/CEA (Ref.14).

TABLE XVI - ENERGY USE & SAVINGS IN AUTOMOBILE METALS

METALS & ENERGY		1958	1966	1970	1970 Savings	
					Mod I	Mod II
Steel	(Tons)	1.200	1.190	1.150	1.293	1.062
"	(kRE)*	1264	1257	1214	1366	1123
Cast Iron	(Tons)	.312	.305	.300	.300	.246
"	(kRE)*	77	76	74	74	61
Aluminum	(Tons)	.027	.035	.055	.055	.0045
"	(kRE)*	1045	1348	2120	2120	117
Zinc	(Tons)	.045	.052	.043	.043	.0353
"	(kRE)*	197	228	189	189	155
Copper	(Tons)	.020	.018	.012	.012	.0094
"	(kRE)*	184	167	110	110	86
Lead	(Tons)	.009	.009	.008	.008	.0066
"	(kRE)*	3	3	3	3	2
TOTAL	(kRE)*	2770	3079	3710	1954	1554

*kRE=kWh Resource Electricity, computed at 3.07 times consumption.

Source: E.Hirst (Ref.16).

Such efforts might be expected to have two main consequences. Constraints (whether economic or regulatory) on the substitution of aluminum for steel and lumber would mean that use of aluminum would tend to be confined to products in which it contributes an essential and non-trivial function, as in aircraft. (Aluminum furniture might be eliminated, for instance.) Constraints on the rapid expansion of the chemical industry would retain dominance of cotton and woolen, rather than synthetic, fabrics; plastics would be used, not as substitutes for paper or wool, but only where their unique characteristics are essential.

If a regulatory body were to try to define which uses were essential and which were not, there would be many serious problems. For example, aluminum siding is an energy-intensive material, yet it lends itself to more energy-conserving residential construction. Should it be encouraged or discouraged in particular uses? If each of the materials were purchased for a price which included the full resource costs of the inputs, including energy, and if the lifetime energy-use of a dwelling were well defined for various construction choices, then the builder and owner would automatically make the best social choice whenever they chose the cheapest alternative for a particular dwelling; this is far better than trying to define the alternatives in a regulatory scheme.

The case of aluminum raises another interesting point. If regulators were to ban aluminum from some uses, there would be far less incentive or opportunity than at present for electricity-saving aluminum processes to come into use. (Several promising alternatives exist, but their economic feasibility is uncertain.) On the other hand, if electricity prices rise, they would create strong forces to encourage development of such energy-saving processes. This is the kind of trend toward greater energy efficiency which the 1971 Presidential Energy Message sought to restore.

Perhaps the most significant displacement which has accompanied the rapid growth of industrial power consumption in the United States is the displacement of labor by electricity following the large-scale use of capital equipment in production processes. In some instances, increases in power productivity could require a disproportionate increase in labor because of the reintroduction of hand labor in place of machine operations. There are, however, far more technical changes which would certainly not require reductions in labor productivity.

The fact that power productivity in industry has been steadily declining since 1947 indicates that low energy prices have been inducing industry to substitute low-productivity power for other inputs, including some low-productivity labor. If this trend is halted, or even reversed, the result will be a slower-than-otherwise increase in labor productivity, but a higher-than-otherwise employment. (Lower unemployment generally means adding less productive workers, hence lower labor productivity; this is not a fault in energy conservation.)

STRATEGY I-3: Promote Energy-Saving Materials in Construction. Additional energy savings are possible in the building industry. It has been suggested (Ref.14) that structural safety standards are generally pyramiding in nature and that reductions in these safety standards would not increase the real risk of disasters, but would permit, for instance, concrete structures to be designed with less than half the material now used. For buildings, there is a cumulative savings, since the weight of the building itself is substantially reduced. The size of the footings can be considerably reduced, with further material savings, reflecting both the more realistic structural analysis and the reduced loadings that the foundations and footings are designed to support. In cement production alone, there would be resulting savings of about 20 billion kWh/year; enough energy savings to provide the electric energy of 3 million families. Table XVII gives a summary of electrical use in building construction.

In the construction industry the use of different materials also requires different amounts of energy consumption. For example, synthetics and plastics, as noted above, generally require more energy than the natural materials that they displace, because the processes of making them require large ratios of energy to basic materials (petrochemicals) in order to break them down and rearrange their molecular structure into the product filaments and powders.

The large energy requirement of aluminum refining (about 5 times the energy requirement of steel on a poundage basis) is due to a major electrolytic requirement. (This process is highly efficient in relation to the molecular bonding energy required; but other processes, mentioned earlier, may succeed in bypassing the requirement for the energy to be electrical.)

Replacement of aluminum by steel is possible, for example, in the construction of office buildings. A Chicago office building required 4 million pounds of aluminum for the exterior covering. This could be replaced by about 5.75 million pounds of stainless steel and would have the same structural and weathering characteristics. In energy terms, the aluminum would require 2.1 million kWh to process and assemble, about three times the 0.77 million kWh necessary for the stainless steel. The difference would therefore be about 1.3 MkWh on this building alone. (The cost-effectiveness of such a substitution depends on the prices, including energy costs, of the choices. Replacing aluminum pipe guard rails along roadways with galvanized steel in New York City was cost-effective, and resulted in energy savings of approximately 1.6 BTU per twenty-foot section.)

TABLE XVII

ELECTRICAL USE IN BUILDING CONSTRUCTION

	Total sales of this item to building construction industry (excluding highways) in GNP (million $)	Total cost/$1,000 for this item for all electric energy	Cost/$1,000 of this item for electric energy, applied directly	Total cost. All electric energy This item (million $)	Cost, electric energy applied directly. This item, (million $)	Cost. Electric energy applied indirectly. This item, (million $)	Rate. Electric energy this industry (¢/kw-hr)	Average rate. Electric energy. All industries (¢/kw-hr)	Electric energy directly used (million kw-hrs)	Electric energy indirectly used (million kw-hrs)	TOTAL ELECTRIC ENERGY (million kw-hrs)
Electric lighting and wiring equipment	1,786	17.60	4.61	31.5	8.25	23.25	1.05	0.875	790	2,660	3,450
Heating, plumbing, structural metal products	9,557.6	21.10	4.33	201	46.2	154.8	0.78	0.875	5,920	17,600	23,520
Other fabricated metal products	1,524.4	20.07	6.39	31.6	9.72	21.88	1.43	0.875	680	2,500	3,180
Primary copper manufacturing	2,007.6	28.9	6.55	58.2	13.13	44.9	0.74	0.875	1,780	5,130	6,910
Primary aluminum manufacturing	78.2	61.4	30.63	4.8	2.4	2.4	0.32	0.875	720	280	1,000
Primary iron and steel manufacturing	2,950.6	28	13.90	82.5	41	41.5	0.78	0.875	5,250	4,750	10,000
Stone and clay products	8,785.3	27.20	14.82	239	130	109	1.04	0.875	12,500	12,500	25,000
Lumber and wood products except containers	5,872	16	6.63	94	39	55	1.23	0.875	3,160	6,290	9,450
Petroleum refining and related industries	1,303.9	16.3	5.38	21.3	7.02	14.28	0.74	0.875	950	1,630	2,580
Electric utilities	214.6	107.3	56.02	23	12	11	0.87	0.875	1,380	1,260	2,640
Gas utilities	42	9.6	0.94	0.4	0.04	0.36	0.12	0.875	30	40	70
Motor freight transportation and warehousing	1,719.7	8.5	3.37	14.6	5.79	8.81	0.875	0.875	660	1,010	1,670
Wholesale and retail trade	8,530.2	17.1	12.34	145	105	40	0.875	0.875	12,000	4,570	16,570
Business services	4,050.1	15.5	7.83	62.8	31.6	31.2	0.875	0.875	3,620	3,570	7,190
											113,230 million kw-hrs

This represents electric energy use in 38.5 percent of the construction industry's share of the Gross National Product (excluding highways) 49.3 percent represents materials; 39.2 percent represents value added. Extrapolating for 100 percent produces a figure of 128,000 million kw-hrs. Total US production of electric energy in 1969 (according to Edison Electric Institute) was 1,556,996 kw-hrs.

Sources: Scientific American, "The Input/Output Structure of the United States Economy," 1970; US Census of Manufacturers, 1967.

STRATEGY I-4: Promote Investments in Energy-Saving Equipment.

The steel industry used 58% of the energy consumed in the primary metal market in 1963. 51% of this was used in blast furnaces and steel mills. It has been estimated that by the year 2000 there could be a reduction of from 25% to 39% in energy consumption, as a result of substitution of the basic oxygen process and other related reduction processes in place of those currently in use.

A number of add-on modifications are currently available, and cost-effective even at current prices, for the saving of energy in heat-intensive applications. Such energy saving devices as heat wheels could result in as much as a 30% reduction of energy use in appropriate applications. Suitable insulation on gas-fired vacuum furnaces, advanced heat-pipe technology, and known improvements in heat transfer and combustion techniques can reduce energy use in some steelmaking activities by as much as 75%.

Even more relevant, an optimum set of such modifications can be installed so as to yield a return (in saved energy costs) of some 60% to 90% (depending on amortization) on the investment cost of the modifications. The fact that such opportunities are being ignored by industry prompts some further questions on the whole topic of the effectiveness of price-based strategies in changing energy use. If a firm is ignoring as 60% return, will they respond to energy price increases that make the return 70% or 75% for their investment in energy saving? Or are the numbers themselves incorrect?

Such energy savings have been validated by specific installations of the equipment in question, which is within current state of the art. It seems that industry generally places a considerably higher price on initial capital costs for energy-using equipment than on the energy bills for that equipment. Why? Further research is needed; it may be that there is a distrust of projections on energy savings (standardization of energy-use characteristics could help), or that industry is responding to differences in tax treatment of capital costs relative to operating costs (so that investment tax credits related to energy conservation might help), or that industry is responding to uncertainty about the future availability of specific energy sources (so that more confidence in both the energy system, and the role which EPA might play in regulating use of specific fuels, would help.) These are obviously serious questions.

An interesting and constructive example of the role of environmental protection is emerging in the paper industry. So-called "dry processing" is being introduced, partly in response to controls on water pollution. In this process, pulp is 97% water rather than 99.5% water; the direct effect is that only one-sixth as much water is used, and the final effluent is six times as concentrated, making for easier removal of the more concentrated pollutants. The interesting indirect effect is that only one-sixth as much energy is required for drying the final paper; this is an 84% reduction in energy use.

Because of the myriad uses, noted above, that energy finds in industrial processes, and the thousands of variations in these processes, the magnitude of a tax credit or penalty which might be used to induce energy-saving technical changes is impossible to determine in an a priori fashion. Specific industry studies are needed in order to determine the size of the economic incentive credit or tax which would induce the adoption of these techniques. Such a data base does not exist at this time, and therefore meaningful estimates of the magnitude of these mechanisms cannot be derived at present.

STRATEGY I-5: Encourage Energy-Saving Shifts in Illumination.

Lighting is responsible for 24% of all electricity sold in the United States. Consolidated Edison has estimated that the percentage of electricity that goes into lighting is as high as 65% due to large commercial and industrial applications. In their area, it appears that substantial savings could be made by eliminating unnecessary lighting. Energy savings could be achieved by substituting fluorescent lamps for standard filament bulbs. Estimates of the AAAS/CFA Power Study Group (Ref.14) indicate that adequate lighting could be installed in institutions, commercial buildings, and schools with less than 50% of current energy use. More selective switching arrangements could result in additonal savings, as well as eliminating usage of artificial light when adequate daylight exists. Air conditioning loads could be lightened, since the extra heat created by unnecessary lights would be eliminated. Fever electric fixtures, smaller wiring loads, and reduced size of switch gear would generate further savings. Of some 5400 million kWh that are used in the construction industry for electric lighting and wiring components of buildings, at least 25% or 1350 MkWh could be saved.

It has been indicated above that the proposed technical modifications in industry could probably be implemented with minimum shifts within the industrial sector. But the strategy of reducing electrical demand by regulating the pattern of use might, nevertheless, have serious consequences. Such reductions might not be possible without changes in the economic factors which govern industrial production and the distribution of wealth, and dislocations of industrial production. It must be understood that these impacts are not by any means certain outcomes of policies to reduce industrial energy demands, but rather they are possibilities on which further research is required, and about which we must be constantly concerned as conservation policies take effect.

Whatever these impacts of demand reduction, they are sure to be less efficient and equitable if we rely on regulation alone than if we allow the price system to furnish the basic incentive for conserving energy. If energy becomes more expensive, the strategic areas where demand will decline are probably those which have just been listed. They are identical with the areas where direct controls would be applied if controls were our only tool. If prices are allowed to rise, strategic intervention will be necessary only where cases of market failure develop.

The strategies suggested above to induce the estimated benefits presented in this section are essentially implementable in the short-run period 1972-1975. In addition, other short-term measures which would be supportive to them include:

1. Government sponsorship of research and development on specific energy-saving industrial technologies.
2. Additional research on the energy-use implications of industry-wide recycling of energy-intensive metals.
3. Regulations specifying minimum levels of efficiency of energy use for industrial machinery.
4. A program of rating the life-cycle energy requirements of alternative industrial processes and equipment.

Strategies for the mid-term and long-term (1976-1980 and beyond 1980, respectively) would encourage further implementation of the short-term strategies where necessary, and in addition would direct some attention to the building of demonstration projects utilizing the total energy system approach to energy conservation.

Unfortunately, it has not been possible to perform an analysis which would detail the aggregate savings possible in industrial energy use. We are well aware that this report is only a fragmentary sample of energy uses and possible savings. But it is noteworthy that the heaviest users of energy consistently are given the lowest prices, hence the least incentive to save.

Table VII projected an industrial energy saving of 3.3 Quads in 1980, and 6.8 Quads in 1990, due solely to electric rate adjustments which left industry's average rate unchanged, and only altered the marginal rate.

As we noted earlier, industry's share of energy use is projected to grow from 41% now to 50% in 1990; from 30 Quads to 70 Quads. Remember that most of the 1990 demand must be from capital equipment that does not yet exist (assuming 20-year equipment life and a 3-year lead time means that about 60 Quads of 1990 projections will be from equipment not yet on the drawing boards.)

In Section III.A we calculated that appropriate residential energy savings would become economical if there were net increases in energy prices of about 25%, in addition to the no-net-cost revisions of electric rates which increased marginal rates about 11%. The residential ratio of added environmental costs to internal rate revisions, and the ratio of their effects, was about 2.5:1. It appears reasonable to assume that this same ratio would apply to the impacts of the two kinds of rate increases upon industry. In this case, increases of energy costs due to scarcity and environmental costs would motivate further savings of about 17 Quads in 1990, in addition to the 6.8 Quads just mentioned; a total saving of 24 Quads of industrial demand in 1990. This saving is relative to a projected demand of 70 Quads; it would be achieved if industry's new equipment during that period aggregates only 36 Quads, rather than 60 Quads, of energy demand. Even while making such a shift toward processes and products that use less energy, industry's energy use would still grow by 53%, and its share of national energy use will still grow from 41% to 46%.

The dynamics of the free enterprise system are such that this saving (a 40% decrease in energy-use by new equipment over the next 15 years) should be readily obtained by means of net increases of only 25% in the real price of energy. Such increases would induce energy-saving production methods, and a slowing of the trend toward energy-intensive materials; these would compound into the total savings mentioned. This need not mean a slowing of economic growth, but only a shift away from ever-greater reliance on cheap energy.

SECTION V

THE TRANSPORTATION SECTOR

GENERAL DISCUSSION

According to Hirst (Ref.15), the transportation sector consumed 16.5 QBTU of fuel and operating electrical energy in 1970, which was 24% of total U. S. energy consumption. Over 95% of this energy comes from petroleum; the transportation sector is the Nation's number one user of petroleum, consuming more than half of the annual total. A more graphic view of this rate of consumption may be obtained by noting that the entire Alaskan oil strike is considered to contain about 100 QBTU of petroleum, about enough to supply the transportation sector for six years at 1970 levels. Projections to the year 2000 estimate that transportation will keep its one-quarter share of total U. S. energy consumption, with an annual sector consumption of about 21.5 QBTU by 1980 and 42.9 QBTU by 2000.

Fuel energy alone does not fairly represent the total impact of the transportation sector on energy resources. If the energy consumption of transportation activities such as road building, fuel refining, vehicle manufacture and maintenance, raw material production, etc., are included in the total, the sector's share of total consumption is considerably greater. For instance, Hirst estimates this additional energy to be over 7 QBTU annually for automobiles alone; although this estimate seems high, we may expect that the transportation sector's true share of total U. S. energy consumption is over 35 percent.

We have already discussed some of these indirect costs in treating the industrial sector, where we were concerned with manufacturing alternatives. Nothing was said there about reducing the total production for any particular use, as by reducing the total need for, and number of, automobiles. In this discussion, we will also not treat the savings on indirect energy costs, mainly because little is known about the relative energy costs, for instance, of manufacturing a transit system rather than a highway/auto system.

Pathways to Conservation

There are three pathways towards conserving or reducing the consumption of energy for transportation: we can reduce the transportation demand; shift traffic toward more energy-efficient modes; or increase the energy-efficiency of existing modes by technological change, better utilization of present technology, or improving vehicle load factors in present modes. Each of these pathways may be applicable to the four major transportation sectors: inter-city freight traffic; urban freight delivery; inter-city passenger traffic; and urban passenger traffic. However, selection of major pathways and specific solutions to the energy conservation problem must rely on an analysis of the character and importance of the transportation sectors and travel modes.

It must be noted that U. S. transportation is dominated by the least-efficient (in terms of energy consumption) transport modes. In addition, these modes are increasing their share of the transportation market. Table XVIII shows a breakdown, by market and energy consumption, of all significant transport modes within three of the four important sectors of the U. S. transportation system. (The remaining sector, urban freight delivery, is dominated by truck transport.) The table also compares the energy-efficiency of the various modes. Inspection of the table leads to specific observations about the three sectors.

Inter-City Freight

The two most efficient modes, pipelines and waterways, play an important and growing role in inter-city freight transport. However, it is suspected that there is little that the government can do directly to effect a significant shift from less efficient modes to these two. Future growth in the pipelines' share of the freight market may come from the shipment of bulk solids in slurry form; existing market incentives should be sufficient to encourage this growth. It is certainly clear that ICC rate-setting policies shift traffic between modes; what is uncertain is the net effect of these shifts on energy consumption.

Although railroads presently have 35% of the freight market, their market share has been declining in competition with trucks and pipelines. From an energy standpoint, any shift in market share from railroads (efficiency of .00147 ton-mile/BTU) to trucks (.00043 ton-mile/BTU) is undesirable. This area deserves further analysis.

TABLE XVIII - MODAL SHARES & EFFICIENCY BY TRANSPORT SECTOR

MODE	FRACTION OF RAIL EFFICIENCY	1970 SECTOR MARKET SHARE, %	CHANGE, SECTOR MARKET SHARE 1950-1970	1970 SHARE OF TRANSPORT ENERGY, %
INTER-CITY FREIGHT				
Rail	1.00	35.	-22.	3.19
Truck	.29	19.	+ 3.	5.95
Waterway	1.26	27.	+12.	1.95
Pipeline	1.51	19.	+ 7.	1.15
Air	.02	.15	+ .12	.74
INTER-CITY PASSENGER				
Auto	.85	87.	-0-	20.08
Air	.35	10.	+ 8.	5.70
Bus	1.81	2.	- 3.	.22
Rail	1.00	1.	- 5.	.20
URBAN PASSENGER				
Auto	.51	97.	+ 7.	33.82
Bus	1.11	2.	- 4.	.32
Rail	1.00	1.	- 3.	.18
Bicycle	20.50	-	-	--

Source: Hirst (Ref.15), modified.

The air freight market has been expanding rapidly; however, it still controls only a tiny share of the inter-city freight market. Although the extremely low energy-efficiency of the airplane makes air freight an undesirable (from an energy standpoint) transport mode, the Department of Transportation estimates of air freight growth show no urgent need for government intervention. On the other hand, a report of the FCST Energy R&D Goals Committee (Ref.16) forecasts a dominant role for air freight in the inter-city transportation market. The report presents a well-reasoned argument that may be summarized as follows:

- "Air-eligible" cargo is either high-value cargo or else cargo which can show net economic benefit from air freight's speed;
- less than 20% of "air-eligible" cargo actually moves by air because of poor marketing, air terminal delays, or other reasons;
- present air cargo projections are based only on the national growth of the 20% of "air-eligible" cargo that now flies;
- current trends in airport design and construction and increased marketing will increase the percentage of "air-eligible" cargo that actually flies; and
- reduction of air freight rates, made possible by more efficient ground handling, information, and documentation, will greatly expand the total amount of freight that is "air-eligible".

If these arguments are correct, air freight may experience an order-of-magnitude increase over and above normal increases due to expansion of the economy. This would place air freight in the role of a major energy-using mode. It may be advisable to study this trend more carefully; it will be necessary to determine whether freight bears a full share of airframe and terminal costs, or only the marginal operating costs, and whether increased fuel costs will help prevent such exorbitant growth in an energy-wasteful mode.

Inter-City Passenger Travel

The inter-city passenger sector is dominated by the lowest-efficiency modes, the automobile and the airplane. Buses and railroads are rapidly losing their tiny share of the market; until recently, railroads were vigorously deleting their remaining passenger services. Strong government policy should be aimed at reviving the energy-efficient modes, while increasing automobile efficiency.

It should be carefully noted that no major shifts of inter-city travel modes can occur unless convenient and inexpensive transportation is available within the urban areas, so that inter-city transit passengers will have continued mobility at their destination.

Urban Passenger Travel

The urban passenger sector is dominated by the lowest-efficiency mode, the automobile. Government policy should be aimed at reviving bus and rapid transit modes, and decreasing the automobile's share of the transportation market. In addition, that portion of urban travel which results from unnecessary separation of origins (residential areas) and opportunity destinations (work places, shopping, recreation) may be amenable to reduction through government influence on land use decisions. Finally, measures that will increase the energy efficiency of automobile travel should be pursued.

Because the automobile is ubiquitous, improvements in its efficiency can, at least conceptually, account for greater savings of direct energy use than very heavy investments in particular transportation systems which are each geographically limited. In fact, it is not possible at this time to draw up a very accurate energy balance for alternatives to the auto, because of difficulties in determining how many autos any specific system might replace. Perhaps the most accurate representation would be to say that transit systems which are justified by their ability to alleviate congestion and pollution problems will also save energy, though they may not be justified by an energy basis alone.

Interactions of Energy Strategies

Any energy conservation measure will tend to shift the structure of the transport market to which it is applied. Traffic will expand, contract, and shift from one mode to another whether or not this is what the measure was intended to accomplish. As an example, any measure that is designed to make a transport mode more energy-efficient, and that is cost-effective (i.e., causes total transport cost per unit of traffic to be lowered) will cause traffic to shift from other modes to that one (providing rates are lowered to reflect the lower costs, or, more generally, that costs are fully internalized to the final user). If the shift is from high-energy-efficiency modes to a lower-efficiency mode (for instance, truck transport to air transport), the total energy expenditure for that portion of the transportation sector may actually increase. This is the opposite of energy conservation!

This phenomenon makes it clear that studies of the competition between transport modes must be an integral part of any evaluation of energy conservation strategies. Such studies are dependent upon a knowledge of the modal elasticities and cross elasticities of demand as functions of transport price and service parameters. Unfortunately, the body of data that might allow us to calculate these elasticities and thus evaluate intermodal tradeoffs is very meager. Some studies of demand elasticity do exist, for instance, in the inter-city freight market. However, a brief examination of a few of these reveals their results to be quite contradictory. Scores, perhaps hundreds, of modal split studies of urban and regional passenger travel have been conducted; their results have been shown to be highly area-specific and usually inadequate to predict future travel behavior even in the areas for which they were conducted.

Thus it is clear that we have been unable to fully evaluate the effect of the conservation strategies we investigated on competitive transport modes. However, in all cases we remained alert to modal competition as an important qualitative parameter. The 1972 National Transportation Report (Ref.17) briefly describes a model designed to predict the shifts of modal shares of inter-city freight as a function of changes in service parameters. The Department of Transportation is supporting this, and other studies designed to predict modal split, in an attempt to give policy makers the quantitative tools they need to evaluate transport improvement strategies. It is highly desirable that the Environmental Protection Agency give strong support to these studies; it is also desirable that transportation studies in general pay more attention to energy aspects than they have in most previous cases.

The following three sections discuss transportation energy conservation strategies that could be followed in the "short term" (1973-1975), "mid term" (1976-1980), and "long term" (beyond 1980). Each section first discusses a series of potential strategies for urban freight delivery and passenger travel, and inter-city freight and passenger transport, and then presents a recommended overall strategy for energy conservation.

SHORT-TERM (1973-1975) STRATEGIES

Inter-City Freight

As noted previously, the key issues in energy conservation in this market are the continuing shifts in freight traffic from railroad to truck and airfreight (and from truck to airfreight), which entail a significant decrease in energy-efficiency for the market as a whole. In the near term, improvements in energy utilization may be most accessible through changes in freight rate structures and simple alterations in services.

STRATEGY T-1: Improve the Competitive Position of Rail Freight. The competitive position of rail freight in the inter-city market may be altered either by improving rail's service characteristics, or by changing the rate structure of either rail or of competitive modes. Rail's average costs, in dollars per ton-mile, are on the order of one-fourth to one-fifth those of trucking. For instance, by dividing total revenues by total ton-miles (Ref.17, Tables IV-3 and IV-4), we obtain an average rail freight cost of 1.49 cents/ton-mile, and an average truck freight cost of 6.24 cents/ton-mile. However, these averages are very misleading when comparing the competitive position of rail versus truck freight. Railroads carry much bulk freight which is totally unsuited to truck transport. If freight which is eligible for either rail or truck is compared, "in spite of the railroad's large cost advantage over trucks,. rail rates for specific shipments are only about 20 percent below truck rates for the same shipments." (Ref.17) Also, in comparing costs to the shipper, we must add such items as investments lost due to delayed revenues caused by the rail's slower service, and other factors. Still, the same source (Ref.17) calculates that fully "24 percent of existing truck traffic could move more economically by rail even if there were no improvements in rail service." (However, "the major questions of access facilities and shipper preferences were not considered.") If this 24 percent could be shifted to rail, a savings of 8 billion dollars in transportation costs and .17 QBTU in energy could be achieved annually. The Report (Ref.17) suggests that a major step towards this shift would be for the ICC to allow railroads to lower their marginal rates.

Data presented by Morton (Ref.18) raise serious questions about the practicality of lowering freight rates. The author calculates the price elasticity of rail freight demand to be -.54, which means that a 10% decrease in rail rates wil result in only a 5.4% increase in traffic volume. This inelasticity of demand indicates that a unilateral lowering of rail freight rates could be financially disastrous for the industry, for costs will rise with increased volume, while total revenues actually fall. The author thus argues that changes in rail's service characteristics, not changes in its rates, are necessary to increase rail's dwindling share of the inter-city market. If this is indeed the case, it seems doubtful that significant improvement in rail's competitive position can be achieved in the short term.

On the other hand, it can be argued that what is needed is not an across-the-board decrease of rates for the kinds of bulk cargo which now comprise most of rail traffic, and which is obviously price-inelastic; but rather, a removal of the floor on rates for certain truck-eligible goods, or else simply an increase in the corresponding truck rates. This last is apt to happen anyway, given the internalization of environmental costs associated with both the gasoline and the highways needed for truck traffic. To settle such questions, a much more detailed scrutiny of rates and elasticities for specific goods will be required.

On the basis of findings to date, we recommend further study of ICC rates and regulations with respect to improving rail's competitive position, and more study on ways to improve rail's service efficiency. ("The average speed of a freight train, including allowances for idle, grade crossings, train make-up, etc., is less than 20 mph" (Ref.16).)

STRATEGY T-2: Improve the Energy-Efficiency of Trucks.
Although several changes in truck configuration are possible, the most promising is probably a change in the truck body shell to reduce aerodynamic drag. The FCST Energy R&D Goals Committee (Ref.19) estimates that the typical truck's aerodynamic drag coefficient is twice that of the typical automobile (which isn't so good itself) and three times that of an "ideal" teardrop-shaped vehicle. It is felt that a modest design program, completed in the short term, could result in truck design achieving a 5% reduction in energy consumption (about .05 QBTU/year in 1970, assuming saturation of the inter-city truck market.) Although the energy savings are modest, the cost is negligible.

In addition to changing truck aerodynamics, possibilities for new truck powerplants may be explored. Some additonal efficiency here may come from comparable trends in the automotive sector, which is discussed below; in both, changes in fuel costs will probably be a major motivation for such developments.

Urban Freight

As noted above, the urban freight market is dominated by trucking. This mode really consists of two fairly distinct submodes: (1) the direct delivery of inter-city freight with no vehicle change, entailing the entrance into the city of large tractor trailers; and (2) intra-urban and terminal-urban delivery, often involving the use of smaller delivery trucks and vans.

In the near term, energy conservation in urban freight delivery should concentrate on the planning for (and, where possible, the early implementation of) the following strategy:

STRATEGY T-3: Centralization of Truck Terminals.

As a corollary to terminal centralization, computer techniques commonly applied toward optimizing inter-city shipments must be applied to urban freight delivery. An optimization of urban freight delivery will include combining shipments from different companies, requiring lightly loaded vehicles to transfer their loads at the terminals, containerization of cargo, and possibly the banning of large inter-city tractor-trailers from congested urban areas, requiring freight transfer to smaller delivery vehicles.

Implementation problems which may arise for urban freight centralization include: problems of availability of large tracts of land (for the terminals) close to cities but suitable for industrial-type activity and for heavy concentrations of truck traffic; opposition of small specialty trucking firms that may be put out of business by a combination of terminal centralization and required cargo transfers to smaller delivery vehicles; opposition from drivers who may see the added efficiency as requiring them to spend more hours at high-speed driving, or as eliminating jobs; and product diversity or requirements for special treatment (such as refrigeration) which might restrict consolidation.

The EPA's Office of Planning and Evaluation has computed potential savings for urban freight "clustering" to be on the order of .5 QBTU/year. This analysis is based on the assumption that urban truck traffic is "clusterable" where SMSA population exceeds 250,000 persons (this yields 468 clusters nationally) and that energy savings of 90% (for intercluster shipments) and 33% (for intracluster shipments) are possible.

Inter-City Passenger

One major key to conserving energy in inter-city passenger travel is the shifting of the predominant mode of travel from airplanes and automobiles to mass transit modes. (As pointed out in a previous section, the probabilities for such mode shifts are tied to a simultaneous shift of urban passenger travel somewhat away from the private auto.) There are five main strategies for encouraging such mode shifts.

STRATEGY T-4: Raise Automobile Operating Costs.

Auto operating costs may be increased by: raising fuel prices by increased taxation (related to society's costs, using market forces to pressure increased auto energy-efficiency); establishing tolls, or raising existing tolls, on inter-city highways; and internalizing some previously external costs of auto travel (especially by requiring installation of air pollution control devices.)

Although such policies are certainly possible within the short term, the lack of good alternative inter-city travel modes in this time frame is likely to prevent any substantial shift of mode by the majority of motorists. Thus, the higher costs may simply restrict the mobility of some lower-income groups without creating many compensating benefits.

Two additional implementation problems with elements of this strategy are the increased fuel consumption which is caused by some air pollution control alternatives, and the presence of a very strong pro-automobile lobby which would attempt to head off any attempts to raise Federal fuel taxes or to tax the use of "freeways." On purely economic grounds, it may be argued that highways are fully funded from user charges, and that users should not be charged an extra burden to pay for the development of other modes of transport. However, construction costs are only a fraction of a highway's social and environmental costs; extra user charges would simply be a belated recognition of these costs.

Quite aside from tax rises, new government requirements, and the like, the cost of operating an automobile is very likely to experience sharp increases in the near future on account of normal market mechanisms together with the governmental actions which have already been taken. Increasing demands for added revenues from the suppliers of fuel, together with dwindling reserves, are going to force especially sharp increases in the price of gasoline. If pollution control devices require the use of lead-free gas, another increment is added. Thus, fuel costs may represent a larger share of total transportation cost in the future, and energy efficiency may be a more important factor in modal choices than it is now.

STRATEGY T-5: Increase Energy-Efficiency of Auto by Technology.

A number of physical improvements are available to increase the energy efficiency of the present automobile. According to FCST (Ref.19), four simple changes could all be through the design stage by 1975, and could probably begin reducing total energy demand by 1977 or 1978, with market saturation essentially complete by 1986. These four measures are:

- Require the use of low friction tires.
  FCST calculates the potential fuel savings of a massive switch to steel belted radial ply tires to be on the order of 10%. Additional advantages of these tires include greater tread life, improved stopping ability, and better puncture resistance. It is noteworthy that these tires are being

sold in the replacement market, without reference to their efficiency; if their characteristics were better known, they might be a natural preference as initial tires on new cars, where their tread-life is far more meaningful.

- Promote body shell redesign.
  FCST estimates that aerodynamic drag can be reduced enough to give a potential fuel saving of 5%.

- Promote redesign of power trains.
  FCST estimates that if the power train provided a better match of vehicle load to the engine, fuel savings would be on the order of 10%-15%, at a cost to the customer of $100-$200 per car; or else, as an alternative depending on vehicle use:

- Encourage the use of smaller engines.
  FCST estimates that for an incremental cost of less than $100 per car, autos could be powered by small engines plus a supercharger or turbocharger, to yield performance similar to that obtained with larger engines when needed, but with much less waste in routine operation.

By 1986, these changes would yield an energy saving of about 4 QBTU per year. The dollar value of the savings to the consumer is over $10 billion per year (135,000 BTU/gallon, 36¢/gallon) at present prices. The investment cost to consumers would be about $30-$35 billion dollars, so the program would be cost-effective even at present prices. If fuel prices rise, as seems certain (and desirable, considering environmental costs), then this program could be very attractive from a cost savings as well as an energy conservation standpoint.

The above reductions are worthwhile to the individual owner in most cases, in simple dollar terms; the need is to make them better understood, so that they will be more widely adopted by the owners who would find them beneficial. In addition, there are other options which are further from realization, which are not so generally economical (under some driving conditions, they do not pay for themselves), or which require some of the costs to be paid in non-monetary intangibles. Some or all of these may be worthwhile, depending on the size of the needed energy savings; but they cannot be directly compared with the early and general effectiveness of the above-mentioned choices. They include the use of transmission overdrives, alternative power plants, and a forced shift to smaller cars.

The use of overdrives is actually a specialized version of the power train improvements suggested above. Overdrives are useful only for sustained high-speed driving, but these are exactly the conditions that prevail in inter-city travel. An overdrive can probably be added to present transmissions for about $150. A representative fuel saving might be about 20% in high-speed driving. Assuming that the owner of an overdrive-equipped car might actually utilize the overdrive for 5000 miles per year, a fuel-related savings of approximately $20/year would result, with some additional benefits from reduced engine wear.

Alternatives to the present internal-combustion engine are discussed in the section on long-term strategies.

Any plans to ban or penalize high-weight, high-powered automobile designs must recognize that buyers of these cars are, with full knowledge, already willingly paying a substantial penalty for these designs and may be willing to pay more. Also, the more "efficient" lightweight, low-powered cars may be less safe than larger cars in terms of structural rigidity and high-speed passing reserve.

It should be noted that a significant switch to small cars is already taking hold in today's market (sales of small cars are currently in the neighborhood of one-fifth of the total.) Although average fuel consumption for small cars is presently much better than for large cars -- about 21 miles per gallon versus 13 or so miles per gallon for large cars and "intermediates" -- much of this saving is not due to size alone and there is no guarantee that the present fuel advantage will continue. Much of the fuel consumption advantage of small cars is due to such factors as lower horsepower-to-weight ratios and fewer accessories (air conditioning, automatic transmissions, power steering and brakes, etc.); some present owners of large cars may "switch" to smaller models but may demand many of the fuel-using "advantages" of their previous cars.

It seems clear that the appropriate economic tool for eliminating energy-wasting large cars (or energy-wasting anything else) is an incremental charge on the energy, together with full consumer knowledge of the alternatives.

STRATEGY T-6: Improve Airline Passenger Load Factors.

Present airline load factors are hovering around 50 percent. Shifts in FAA policy which would reduce excess capacity maintained because of competition for traffic on popular routes, and reduce or eliminate scheduled service on little-used feeder routes, might raise load factors and thus substantially improve air travel energy-efficiency. However, many questions of unfair restrictions on competition and discrimination against smaller cities may arise upon attempts to promote this type of strategy. As noted above in considering autos, it is desirable to pursue strategies whose costs are measured in dollars, rather than reduced service and resultant inconvenience. It will also be important to ensure that the airlines are not simply goaded into using the spare planes to carry marginal air freight, at higher energy costs than competing modes.

In addition to all the above strategies, further research is needed on the degree to which various positive and negative flow taxes work on the various modes at the present time. The airlines practice a substantial degree of subsidization of short-haul flights by their longer flights; this wastes energy. Also, property taxes paid locally by railroads (as against public right-of-way for trucks) need more study of their energy role.

Urban Passenger

Conservation of energy in the urban passenger travel sector has a variety of potential strategies available for the near term. These focus primarily on promoting mode shifts from auto to transit and improving the energy-efficiency of the dominant auto mode.

STRATEGY T-7: Raise Urban Operating Costs of Autos (Parking, & T-4). The only tactic this adds to Strategy T-4 (for Inter-City Passenger Travel) is that of raising parking fees. But increases in parking fees may well be the single most effective short-term method of promoting car-pooling and shifts to transit. It has been shown that highly visible costs — such as parking fees — are far more important determinants of travel behavior than are the somewhat less visible fuel costs, maintenance costs, automobile depreciation, and the like. Recent experience in the District of Columbia has shown that the characteristics that make a parking tax effective in influencing travel behavior — high visibility — also make such a tax highly unpopular and thus politically hazardous. However, this obstacle might be substantially mitigated if good alternative transportation is provided, and the tax should be a reasonable longer range measure.

It must be remembered that this report has constantly stressed the need for internalizing environmental costs. With respect to auto emissions, this means that the optimal approach would be to charge for the social costs associated with the use of each gallon of gas. These costs vary with the location where the gasoline is used, and with the emission characteristics of the vehicle.

Consider a commuter who lives fifteen miles from work, and burns 10 gallons of gas a week commuting. Even a 25% surtax or emission charge on his gas would be only about $1.00 per week, the same as a 20c parking tax. It could pay the commuter to drive up to 50 miles from town to buy gas without the tax, even if he bought only what his tank would hold. If all gas within 50 miles of town carries the surtax, many people are paying extra even though they never drive into town. If such a fee is enough to discourage commuting, it is probably enough to encourage drivers to disconnect their emission-control devices to get better gas mileage. There is no practical way at present to make the tax proportionate to the emission characteristics of the vehicle, or to check for disconnected controls. All these problems grow worse as the tax rises; yet most people would agree that 20¢/day would not make a major impact on commuters, since it is the opportunity cost of only about 2 minute's waiting time each way.

In many ways, a tax collected at the parking space can come closer to a valid price on externalities than a surtax on gasoline purchased. At the parking space, the tax (especially for monthly spaces for commuters) could be made proportionate to both the vehicle's characteristics and the distance from the commuter's home; and the vehicle could more easily be subjected to occasional spot checks of emission controls while parked than while moving on the highway. A tax approaching $1.00/day for uncontrolled cars, scaling down to zero for cars which meet 1975 standards, might make a 10-minute delay for transit or car-pooling worth while for the uncontrolled cars, and might accomplish at least as much as a very large gasoline tax toward both pollution control and energy conservation in cities.

An additional alternative here is, of course, simply to ban autos from the center city during business hours. Although this policy has frequently been advocated, it seems clearly impractical in most cities where transit cannot handle the increased load or provide the required flexibility, at least in the short term. For the longer term, severe problems still exist; these will be discussed in a later section.

It is to be expected that severe pressure would be brought against such a strategy, generated by commuters, retail establishments, parking garages, and so forth.

STRATEGY T-8: Subsidize Short-Term Improvement of Existing Transit. Improvements which might be made in the short term include increased levels of service, replacement of obsolete vehicles, lowering of fares, and the use of exclusive lanes where feasible. Funding for such efforts might come from the Highway Trust Fund, or more directly from gasoline taxes or parking fees. (The latter arrangement is a carrot-and-stick approach; those who choose to drive pay a fee which helps keep both the air and the streets clear enough so they can have this convenience.)

This kind of strategy is difficult to evaluate quantitatively. The effects of transit improvements cannot easily be extrapolated outside the areas where they have been tried. For this reason, generalizations are dangerous. Hedges (Ref.20) refers to transit improvements in Boston and Peoria, Illinois. The instigation of free transit was calculated to reduce Boston auto work trips by only 6%-7%, with even less change in the volume of non-work trips. A Boston demonstration project which reduced transit fares by 24%-30% increased peak hour riding by only 2%. On the other hand, the Peoria demonstration, a very fast commuter bus service, attracted 542 daily riders, of whom 75% has previously used the automobile. The results of other transit experiments can be discussed almost without limit, but they mainly confirm that the record is haphazard.

Although we strongly recommend a carefully conceived program to expand existing transit services, we are not able to venture an estimate of the results in energy conservation. As we have mentioned before, transit's main benefits seem to be in controlling pollution and congestion in urban places where the existence of transit can be justified; comparable investments in auto efficiency would yield nationwide energy savings which are larger. (One estimate, by FEA's Office of Planning and Evaluation, is that shifting to small cars throughout a given urban area saves just as much energy as shifting 70% of the commuters to buses.)

STRATEGY T-9: Promote the Use of Fringe Parking Facilities.

Unfortunately, fringe parking is practical only where very efficient transit service is available. Inherent problems of personal safety, discomfort in inclement weather, and loss of commuting time in transferring between modes are difficult to overcome. The availability of large tracts of close-in suburban land is questionable in many areas, and neighborhood opposition to such a traffic concentrator may be substantial. There are also some questions about the net energy efficiency (and pollution) of warming up an automobile just to get to the transit line.

STRATEGY T-10: Initiate the Restructuring of Urban Transportation.

Most of the suggested short-term energy conservation measures for urban transportation are very limited in nature. Mid-term and long-term measures will require massive planning efforts for successful implementation. Some of the more straightforward measures that could be suggested for the mid-term (1976-1980) -- for instance, exclusive bus lanes and computerized traffic control systems -- can be fully planned and/or designed by 1975 or earlier.

If history is any guide, the most favorable focus for mode-shifting strategy will be the urban work trip. Urban commuting has traditionally been the mainstay of transit systems and will probably remain so. Present government programs provide considerable support for planning efforts in this area, and these programs should be continued and expanded. Additional emphasis should be placed on the energy requirements of various alternatives, and on the effects of price shifts on the demand for those alternatives.

Strategies for improving the efficiency of the automobile include:

STRATEGY T-11: Promote Technological Improvements of Autos (T-5).

Energy savings in the urban-travel sector will be somewhat different than those experienced in the inter-city sector. For instance, transmission improvements will have a greater impact on urban driving whereas aerodynamic improvements have the most impact on inter-city high-speed driving.

STRATEGY T-12: Promote Carpooling.

In addition to the pressures exerted by increased costs of auto operation (as in T-7), it would be possible to establish computerized carpools, or to give some form of preferential treatment to automobiles with three or more occupants.

Inter-city automobile trips have high load factors — about 2.4 occupants, averaged on a passenger-mile basis -- and incentives for carpooling are probably wasted in this sector. Urban auto travel, on the other hand, has low occupancy rates. Hirst (Ref.15) uses 1.4 occupants per car, though other data support somewhat higher estimates. In addition, this mode and sector has a very high total energy consumption -- 34% of the total consumption of the whole transportation sector. A strategy which results in a 10% increase in vehicle load factors would save about .6 QBTU per year, assuming total demand for travel service was unchanged. Unfortunately, there are no data that show exactly what it might take to achieve such an increase in load factor.

All the above strategies will partly cause, and partly be helped by, traffic flow improvements. Some such improvements might include reversible lanes, one-way streets, stagger-timing of traffic signals on major corridors, and strict regulation and enforcement to prevent motorists and trucks from double-parking, blocking intersections, and so forth.

Measures that promote smooth traffic flow of all urban vehicles constitute something of a two-edged sword in an energy conservation program. Although such measures prevent the waste of gasoline and the production of pollutants through excess idling time and acceleration cycles, and improve the service of urban buses, they also make driving more attractive and thus complicate the effort to shift commuters to transit.

Suggested Strategies

Based on the above discussion, several energy strategies for the near term seem particularly worthy of attention:

Stimulate Increased Energy Efficiency in Automobiles, by

(1) Technology/Design/Vehicle Size
- radial tires, especially on new cars
- better load-to-engine match in power train
- smaller cars, especially for urban commuting
- decreased aerodynamic drag
- small-engine-plus-booster for large engines

* POTENTIAL ENERGY SAVINGS: low in short term, about 4 QBTU by 1985 (30% fuel savings.)

* COSTS: investment of $30 billion by total car population less fuel savings of $10 billion/year at current prices, and lower costs for small cars.

(2) Promotion of Increased Use of Car Pools, by
- increased parking fees
- computerized matching
- preferential treatment

* POTENTIAL BENEFITS: about .6 QBTU by 1975 with 30% increase in commuter car occupancy; and less urban congestion.

* COSTS: low net cost: parking fee would be a transfer from drivers to transit & car pool riders.

(3) Stimulation of Research into Power Plant Alternatives.

* POTENTIAL BENEFITS & COSTS UNKNOWN.

Improve Existing Mass Transit Service in and between Cities -

* POTENTIAL ENERGY SAVINGS: unknown but probably low.

* COSTS: Variable.

Plan/Design Centralized Systems for Urban Freight Delivery -

* POTENTIAL ENERGY SAVINGS: none in short run.

* COSTS: $25,000-$500,000 per urban cluster.

Maintain Railroad's Share of Inter-City Freight Market -

* POTENTIAL ENERGY SAVINGS: Low in short run.

* COSTS: $200,000 for preliminary studies.

Begin to Restructure Urban Transportation -

* POTENTIAL ENERGY SAVINGS: None in short run.

* COSTS: $50,000-$5,000,000 per urban area for plans; more comprehensive efforts into mid-term.

MID-TERM (1976-1980) STRATEGIES

Inter-City Freight

Based on the results of the studies of ICC rates and regulations which are suggested for the 1973-1975 period, the following strategies may be indicated: increase taxes on trucks; provide direct subsidies to rail freight; and/or provide construction and maintenance grants for new rail freight facilities, including terminals and right-of-way. All of these measures will be subject to protest by competing interests; it is essential that we develop adequate understanding of the interactions among all present subsidies and the role of regulated prices.

Plans should be developed for making rail freight technologically competitive with truck freight. Strategies might include the massive use of automated freight handling equipment and computerized scheduling, and the exploration of trade-offs between energy-efficiency degradation caused by high-speed operation of freight trains, vs. improved competitive position of rail freight through improved delivery times.

It is worth repeating here that we have not obtained the type of data that would enable us to explore some of the implications of the above strategies in a quantitative manner. The 1972 National Transportation Report (Ref.17) had held out some hope that we could present the results of a mid-term rail strategy that accomplished a 20% increase in rail freight speed (the 20% is input to the model; no actual strategy is defined.) However, we could not reconcile the results with the study assumptions (although a key study assumption was that total traffic remained unchanged, the summation of the modal changes did not add to zero) and we were forced to temporarily abandon this effort.

Despite this lack of appropriate quantitative methods, we can demonstrate in a very rough manner the type of energy savings available. We do this by calculating the savings obtained if the 1980 freight modal split were somehow replaced by a return to the 1960 modal split (which is more favorable to rail transport and considerably less favorable to air freight.) Table XIX was derived in this manner, with the assumption that modal energy-efficiencies remain constant with time, by applying the 1960 splits to 1980 traffic and calculating the resultant total energy, then comparing it to the actual 1980 energy forecast for inter-city freight. We obtain an energy savings of about .4 QBTU in 1980.

A final strategy for this subsector is to pursue higher energy-efficiency in trucks. The substitution of higher-efficiency powerplants in trucks must receive continued study. There are also

TABLE XIX - RETURNING 1980 FREIGHT TRAFFIC TO 1960 MODAL SPLITS

Mode	1960 % of Ton-Miles	Efficiency BTU/T-M	1980 Projected Traffic	1980 Projected Energy	1980 Modified Traffic	1980 Modified Energy
Air	0.05	37000	14	518	1.5	56
Truck	18	2340	537	1257	530	1240
Rail	38	680	967	658	1118	760
Water	25	540	811	438	736	397
Pipeline	19	450	614	276	559	252
Totals			2943	3147	2943	2705

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Energy Savings in 1980 = .442 QBTU/yr....../..................../

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TABLE XX - RETURNING 1980 PASSENGER TRAFFIC TO 1960 MODAL SPLITS

Mode	1960 % of Pass.-Miles	Efficiency BTU/P-M	1980 Projected Traffic	1980 Projected Energy	1980 Modified Traffic	1980 Modified Energy
Air	4.3	8400	314	2633	83	696
Rail	2.8	2900	9	25	54	156
Auto	90.4	3400	1575	5355	1737	5900
Bus	2.5	1600	27	43	48	77
Totals			1922	8056	1922	6829

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Energy Savings in 1980 = 1.227 QBTU/yr...../..................../

opportunities for major savings through reductions in aerodynamic drag. In the discussion of short-term strategies it was indicated that a 5% savings in truck fuel consumption was possible, with a "negligible" R&D effort on lowering the aerodynamic drag of current vehicles. FCST concludes (Ref.19) that a "moderate" level of R&D and production engineering could produce a 20-30% energy savings in the mid-term. This would amount to roughly a .5 QBTU/year savings by 1985, assuming near saturation of the truck market.

Urban Freight

Strategies should continue to focus on improvements in the energy-efficiency of present and slightly modified truck delivery systems. However, planning should also begin for utilizing new modes of urban freight movement. There are several specific strategies for this. Centralization of truck terminals and computerized optimization of freight deliveries might be required in all major urban centers. The use of energy-efficient electric delivery trucks should be explored. Advanced planning for new urban transportation systems must include freight movement as an integral factor. Possibilities of using high-speed automated freight handling equipment in conjunction with dual-use (i.e., both passenger and freight) transit systems should be explored for implementation in the 1980's and beyond. Obstacles to these measures will be similar to those for short-term measures for freight improvement. Those providing present services may be expected to voice opposition to any plans to change the present system, even where it is clearly inefficient.

Inter-City Passenger

In the mid-term, a strategy for reducing energy consumption for inter-city passenger travel can utilize the three pathways discussed previously -- shifting of demand to energy-efficient modes, traffic reduction, and increases in modal energy-efficiencies. There should be a continued promotion of increased energy-efficiency in the automobile. The concept of exclusive bus lanes might be extended to inter-city travel. Although it would be quite expensive, high-speed rail service might be provided in all major inter-city corridors.

Research should be supported for new high-speed inter-city transport modes, and demonstration projects might be instituted. High-speed inter-city travel modes, whether based on rail transport or on some other mode, will consume a very large amount of energy; they must therefore carry a considerable number of passengers in each train or vehicle in order to fulfill their energy-saving potential. Thus, Metroliner-type service in inter-city corridors makes sense only when passenger load factors can be kept high.

We should institute measures that will ensure efficient connections between inter-city and urban transit modes; this means a requirement for coordinated planning, regional transportation authorities, and linked computer ticketing systems. Among the possible problems are the existence of overlapping and opposing political jurisdictions, and the unwillingness of municipalities to cede control to regional authorities. As with inter-city freight, we cannot quantify the energy savings from the above measures; but we have repeated the exercise of applying 1960 modal splits to 1980 traffic in order to get an idea of the magnitude of energy savings that might be obtained by 1980. Such energy savings come to about 1.2 QBTU/year (Table XX.)

Urban Passenger

In the mid-term, conservation of energy in the urban passenger travel sector may also utilize all three pathways discussed previously. However, assuming that the automobile energy-efficiency measures advocated in the near-term strategy discussion have begun to be instituted in force, the key to any further substantial decrease in energy use lies in reducing automobile travel.

One of the simplest strategies would involve promotion of walking and bicycling to substitute for short (less than 2.5 miles) automobile trips. We should plan for, and construct, pedestrian walkways and bicycle paths. According to the AMA (Ref.21) 54% of all automobile trips are less than 5 miles long. These trips account for 11 percent of automobile mileage. If we assume that half of this mileage is for trips less than 2.5 miles in length, and that we can convert one-fourth of these trips to walking or bicycling (admittedly very optimistic), then the energy savings is about .2 QBTU/year in 1985.

There must be long-range urban/suburban planning aimed specifically at developing multi-use population centers with combined residential, work, and recreational activities. All planning is aimed at some degree of restructuring of urban and suburban life in an effort toward decreasing the environmental costs of urban living. However, it should be noted that much of this restructuring flies in the face of the current living and travel preferences of a majority of urban dwellers.

It is pure conjecture to assume that these preferences are solely the result of economic and social distortions wrought by a pattern of government promotion of the automobile and the single-family house, and the advertising industry's catering to this promotion. Instead, it is far more logical to assume that the flexibility of the automobile and the privacy, security, and sense of ownership afforded by the single-family housing pattern play as important a role in present travel and living patterns as do other factors. It would seem that the restructuring of our living and traveling patterns is a far more difficult sociological problem than has been admitted by many current planners. We would conclude that the planning segment of this restructuring process, as it addresses the more radical and potentially disrupting strategies, must be given a very large resource base, a maximum of initial planning flexibility, and a strong charge to fully address all the sociological and secondary environmental consequences of the restructuring alternatives.

One promising circumstance for such restructuring may be found in the fairly recent trends toward smaller families, and toward larger numbers of childless family units. Planners have often sought to create fully heterogeneous communities, almost as an end in itself; and it has been expensive and difficult (not to say impossible) to design a working/shopping community which would stay amenable to children. Perhaps much of the congestion problem could be alleviated if we at least tried to accommodate the residences of more of the childless within our urban places, even if this means excessively homogeneous areas.

Toward this same end, there should be stronger government sponsorship of the construction of neighborhood activity centers for recreation and leisure, to reduce somewhat the demand for recreational travel.

In the mid-term, all existing transit services should be expanded, with the help of subsidies where necessary. We should begin the installation of advanced transit and traffic control systems which will have been designed in the early and mid 1970's. Such transit systems should be tied into fringe parking facilities in the nearer suburbs.

Although most of the proposed rapid transit systems for some of the nation's larger cities forecast only a very modest modal split (Atlanta, 5% of daily trips; Los Angeles, 2%; St. Louis, 6%; Washington, 5% (Ref.22)) they do not normally represent truly comprehensive systems. If plans for a wide range of transit services are fulfilled, and urban plans for clustered development are followed, then modal splits to transit might become an order of magnitude higher than these forecasts, and savings of several QBTU's per year are possible. Unfortunately, such modal splits are entirely speculative at this time. We must reaffirm the urgent need for demonstration programs and modeling efforts that may allow rational evaluation of alternative transportation futures.

We described a center-city ban on cars as unrealistic in the short run. With the expansion of transit services in cities that is expected to occur in the mid-term, a traffic ban of this sort will become a feasible strategy. However, there are some important obstacles to the acceptance of such a ban. First, a significant number of exemptions must be granted -- for handicapped workers, actual residents of the CBD, and others -- and this will greatly complicate enforcement. Retail establishments within the area may strongly protest, especially if they sell goods that are difficult for the average shopper to carry on a transit vehicle. Finally, a ban during business hours will increase the severity of transit's normally harsh rush hour peaking problem.

Suggested Strategies

Continue Auto-Efficiency Improvements from Short-Term.

Improve Transit Services, by
- Expand/Improve Existing Urban Mass Transit Services
- Initiate New Urban Mass Transit Systems
- Link Urban Transit Systems to Inter-City Modes
- Expand High-Speed Rail Service in Inter-City Corridors
- Build Connected Fringe Parking as Appropriate

* POTENTIAL ENERGY SAVINGS: Speculative, possibly a few QBTU/year by 1985 (beyond short-term savings.)

* COSTS: Variable, but in any event high (several $10 billions); balanced by benefits of decreased pollution and congestion. The DOT Needs estimate is about $65 billion for 1970-1990.

Improve Freight Delivery Efficiency, by
- Terminal Centralization
- Containerization
- Computerized Optimization

* POTENTIAL ENERGY SAVINGS: About half a QBTU/year by 1980.

* COSTS: Unknown.

Stress Transport Energy-Efficiency in All Urban Planning -
- Pedestrian Circulation
- Multi-Use Population Centers
- Neighborhood Activity Centers

*POTENTIAL ENERGY SAVINGS AND COSTS: Variable.

LONG-TERM (BEYOND 1980) STRATEGIES

Long-term strategies for the four major transportation sectors involve implementing those new systems and technologies for which planning was begun in the 1970's:

Install New Motor Vehicle Power Plants

There are a considerable number of power-plant technologies that are candidates for supplanting the Otto-cycle engine in the long term. FCST lists (Ref.19) the following: stratified charge engine; light-weight diesel; advanced gas turbine (open-cycle Brayton); Rankine cycle engine; Stirling-cycle engine; closed-cycle Brayton; and the electric motor. Engine types that lack Federal funding for research include the diesel and the Rankine cycle engines. It is suggested that research projects be initiated for these power plants.

These power plants offer a variety of cost/benefit trade-offs including high or low energy-efficiency and pollution production, and so forth. The interested reader is directed to the FCST Report (Ref.19) for further details of these trade-offs.

The high level of interest in electric propulsion warrants a bit further discussion at this point, however. According to calculations by Crimer and Luszczynski (Ref.23), electrification of all automobiles in the U. S. could save approximately half the total energy that would have been utilized with no changeover. Assuming a target date of 1990 for total conversion of all automobiles, it is estimated that a savings of more than 7 QBTU/year would be realized at this time. The analysis that leads to this result may be questioned, however.

According to Netschert (Ref.24), 65% of the electrical energy supplied to an efficient electric vehicle is used in actual propulsion and 35% is wasted. According to various sources, the overall efficiency of the production and distribution of electricity is about 29% (less for older atomic plants, but about the same for the newest and more efficient plants now under construction.) Thus, the total energy-system efficiency of the electric car is about 19%. Specifically:

> Overall efficiency (19%) = coal production efficiency (96%) * coal transportation efficiency (97%) * power plant generation efficiency (36%) * electricity transmission efficiency (90%) * motor control efficiency (90%) * battery efficiency (80%) * transmission-to-wheels efficiency (90%)

In contrast, the authors compute the efficiency of the gasoline-powered automobile to be on the order of 10%:

Overall efficiency (10%) = petroleum production efficiency (97%) * refining efficiency (87%) * transportation efficiency (97%) * engine thermal efficiency (70%) * transmission-to-wheels efficiency (70%)

Besides this 19% to 10% advantage in converting total energy to propulsion energy, the electric car enjoys the further advantage of not consuming engine energy while idling; an important factor in urban travel.

As far as supplying the requisite amount of electrical energy, the authors compute the delivered energy needs for a population of electric automobiles to be 1.54 QBTU's in 1968 (assuming all 83.7 million cars were electric, and were driven an average of 9,500 miles each in 1968), or 34% of all the electricity sold in the U. S. that year. Given flexible hours of use (e.g., overnight charging) this additional power might be supplied without massive expansion of U. S. electricity-generating capability.

Although the above calculations seem appealing, there are some definite problems with them. For instance, the analysis does not include a battery-charging step; FCST (Ref.19) estimates the efficiency of this step to be about 80%. The average power plant efficiency is closer to 34% than to 36%, and the efficiency of transmission to wheels is given by FCST as 85%, not 90%. Inserting these values, an overall efficiency of 14% is calculated for the electric propulsion system. The gap between electric propulsion and internal combustion (Otto-cycle) engines has been considerably narrowed.

There is also a considerable amount of R&D that will be necessary before a practical mass-produced electric system is possible. Although battery design is the major hurdle, other obstacles such as the design of suitable motor/control packages, system integration, materials problems, and others will block the way to a massive switch to electric cars. It is estimated that a 10- or 15-year program costing $200 million is necessary to bring the electric car to life.

A more pervasive problem is the following issue: given petro-chemical shortages and pollution problems, are we wiser to shift to heavier dependence on nuclear-fueled power plants for electric cars? Or would this be too rapid a move to a technology which may well prove to have its own, and worse, environmental problems?

On the basis of the above discussion, it is clear that it is much too early to make explicit recommendations concerning electric automobiles beyond asking for further study of their potential.

Install New Systems

Earlier sections have discussed the ramifications of new freight handling systems, new mass transit systems, and new urban designs. In addition, there are long-term implications for transportation in the development of new communication systems.

It is worth remembering, always, that transportation is not an end in itself, nor even always a good; a great deal of transportation is simply a necessary evil. We have already applied this philosophy to such matters as reducing the number of recreational trips by providing closer opportunities. Advanced communications systems offer the possibility of eliminating the need for a considerable number of trips — many business trips, delivery of printed material (newspapers and magazines might be "printed" in the home via computer connections), many types of shopping trips (via direct computer links between home and stores) and trips for some transactional business (such as cashing checks or taking out loans.)

The potential for achieving really substantial transportation energy reductions through the use of advanced communication systems might seem limited because those trips to be first eliminated are the short trips. (Food shopping via computerized selection and delivery may be more acceptable -- especially considering the trend towards packaged foods -- than trips involving potential purchases of furniture, clothing, and other goods which often entail longer shopping distances.) However, the success of mail order and catalog stores in selling everything from carpeting to sports equipment to art to electronics gear may indicate that most American consumers would be willing, in time, to do far more of their shopping by means of such communications systems.

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